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DEVELOPMENT DIGEST

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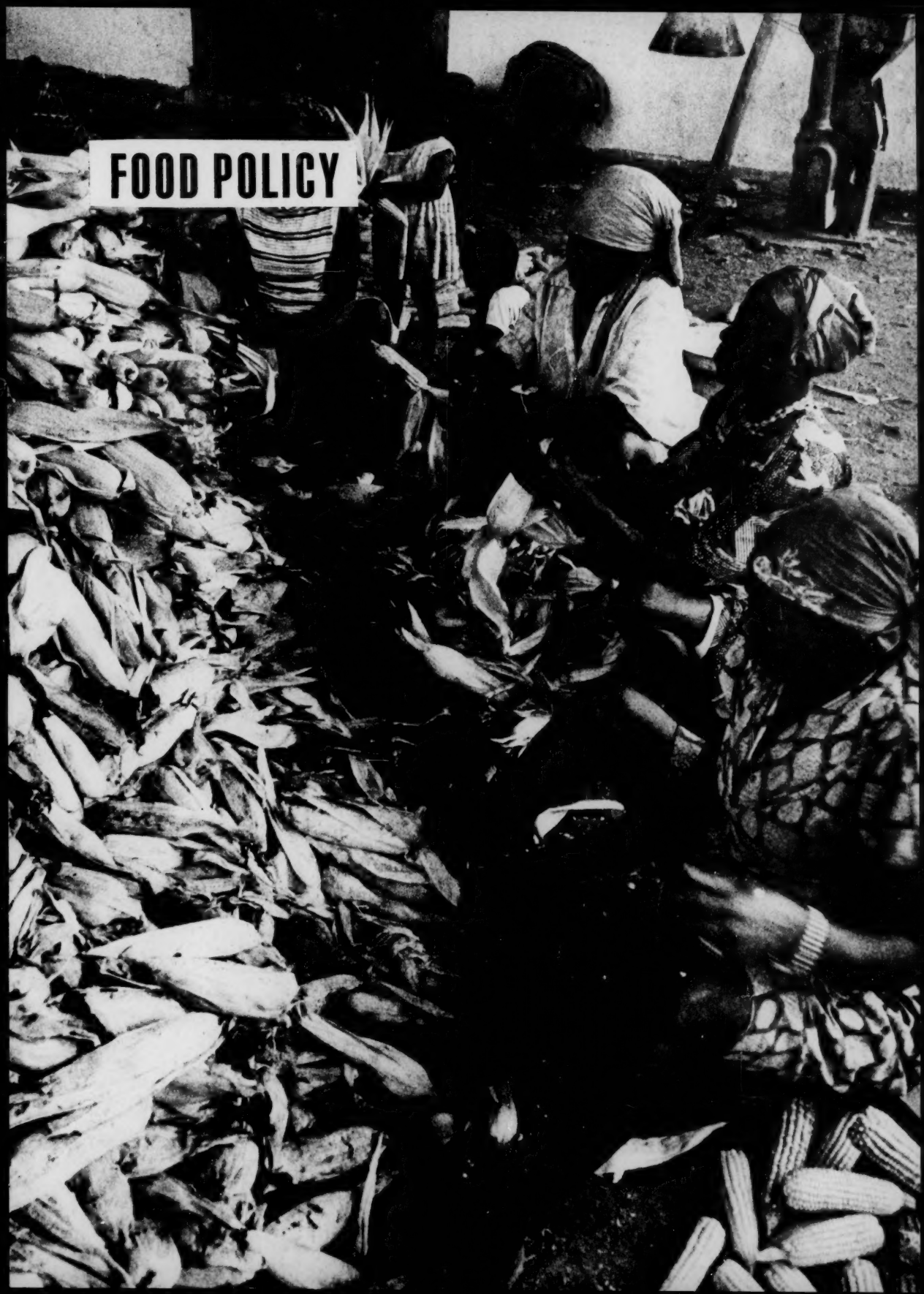
FOOD POLICY



CAMEROON WOMEN HUSKING CORN
(PHOTO: FAO)

POLITICAL DIMENSIONS OF FOOD

Edwin M. Martin

[Food supplies and prices have a number of political dimensions, national and international. Remedial policies suggested here include production incentives for farmers, creation of reserve stocks, and a greater attention to problems of malnutrition.]

Like most things in the modern world, it seems, the politics of food is highly complex. Food problems become political ones in five different ways:

1. Government intervention is frequently invoked by farmers to improve their incomes from food production, and by consumers to reduce food costs. The latter can represent pressure from poor people who cannot buy enough to live if food prices rise, or from those who are better off and resent having to spend more than 15 - 20 percent of their incomes on food, or who insist on a special diet -- usually one high in meat. The latter two are usually the strongest pressure groups in the U. S. The meat lobby overthrew a government in Poland a few years ago, giving the Soviets a scare from which they haven't recovered if one is to judge from their import policies since. The political weight of both groups -- farmers and consumers -- is sufficient to force governments to make very difficult choices.

2. People without enough food are sources of social disorder. Although they seldom have the means or strength to overthrow governments by themselves, they can tip the balance of contending forces -- often a delicate one. More indirectly, the existence of people without enough to eat can be a stimulus to the

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growth of political movements opposing things as they are, often by violence -- movements usually led and composed of rather well-off and well-educated individuals. Usually it is the urban rather than the rural malnourished that governments fear.

3. Less well recognized by most governments of poor countries is the necessity of adequate nutrition to the success of their development plans, both in terms of efficiently producing manpower and of savings on health and education expenditures.

4. Given the domestic pressures on governments to see that their people get enough to eat at reasonable prices, the access to cheap food on world markets becomes a major political objective of food-deficit countries, and hence may become a diplomatic card to be played in inter-governmental relations.

5. Alternatively, governments who have a chance to do so may seek food security by expensive efforts to achieve self-sufficiency, often at the cost of greater malnutrition among their poor.

The food sector is unique in our economies. World demand will go up at least 2 percent a year for at least the next couple of decades because population will do so. Income increases will add something to this demand. It is not very flexible, like that for autos or even shoes, because you can't postpone eating for very long. Faced with steadily growing demand, we cannot control output; weather, and to some extent pests, are still very much in charge with unpredictable effects. Moreover, farming is done by hundreds of millions of "small businessmen", scattered all over the face of the earth and thus hard to reach with changes in technology, new inputs, or new price signals.

Taking account of these factors, the best experts have estimated that over the next ten years -- longer is too uncertain -- the world can produce enough to feed everyone at present levels if past trends in output are met. That last condition assumes that we manage the global economic and political system no worse than we have been doing for the last decade or so; that our governments give an equally high (or low, depending on your point of view)priority to food production in price, tax, investment and similar policies; and that a new mini ice age or other big shift in climate does not emerge, as some have predicted but most experts think is not inevitable.

That sounds pretty encouraging, but is far from the whole story. Present levels of feeding means continuing to have an unacceptable level of half-a-billion people malnourished, 95 percent of them in developing countries, 75 percent in rural areas, 60 percent in South Asia. To get them enough to eat would take only a 30 - 40 million tons a year increase in grain output, or the equivalent of the annual

requirement to meet population growth -- if it all went to them. But present political and social systems seem unlikely to bring that about; and the output increase would therefore have to be several times the indicated tonnage if the malnourished are to be fed, unless new delivery arrangements can be developed.

Furthermore we can expect there to be good years and bad years. With very little grain now on hand beyond normal working stocks and no arrangements for setting grain aside in good years, higher prices in bad years are inevitable. This means not only inconvenience for consumers in all countries but increased rates of malnutrition, and perhaps some increase in starvation, among the people now living on the margins of subsistence because of their poverty, who are often spending three-fourths or more of their income on such food as they do eat. We would need 50 to 60 million extra tons of grain to put in a governmetally controlled world reserve system to take care of bad crop years. In addition, the experts expect that with average crop weather, the present grain deficit of the developing countries will about double to an average of 100 million tons a year, even assuming favorable rates of output increase. The problem is that their populations will for some time be growing some three times as fasst as those of industrial countries; and that poor people, which most of them are, spend a high percentage of any income increase on food. Imports of that volume will be almost impossible for governments to finance, especially as half of the amount is expected to be needed by the present poorest group of developing countries, called by the UN the MS.

I believe that this situation calls for several political actions by the governments of the world:

Production. A higher political priority is needed for food production everywhere, in order to ensure that all needs will be met and food costs to consumers do not increase because of any failure in global output increases. The U.S., in particular, should guarantee incomes to grain farmers, including those on marginal farms, that will cover costs and give a reasonable return for investment and labor. This guarantee must keep up with cost increases -- far from true at present. Even more important, developing countries must realize the importance to the productivity of their own farms of an adequate return to farmers. Prices should not be rigged in favor of the politically threatening urban poor at the expense of incentives for farmers. The same need for better incentives for farmers would seem to apply also to a number of the communist-run countries.

Increased investment in farm production is also required. Most of this must be built up from within the developing countries themselves, but the rich countries must provide more help too. Such government aid should be directed especially to the poor farmer who is usually not able to secure access on his own to new technology, credit, inputs, etc., to improve his methods of production. It will

not be easy to identify the most important of his constraints, including such politically difficult ones as tenure systems, too small holdings, etc., and persuade him to take the risks involved in all novel methods, and for governments to create the institutions necessary to ensure that the improvement process is permanent. Commitments of aid funds from donors, new and old, have been increasing since the 1974 World Food Conference, nearly doubling from 1973 to 1975. But there is a great scarcity of qualified persons available and able to prepare and execute projects which can reach effectively these widely scattered and usually illiterate farmers. Money is currently chasing people in this area, and good managers and communicators can't be turned out overnight. Again governments must do more to persuade good people that their food systems are important and worth devoting their skills to.

Behind all this public activity lies the work of scientists. We are just beginning, from a research time standpoint, to work on the problems of subsistence food crops in the tropics and semi-tropics, especially in terms of the special handicaps of land, climate, pests and money. A far higher priority from governments is needed for national adaptive research in this field, meaning more money from all sources, but, even more, better brains. On all these matters there is some reason to be encouraged by the progress since 1972, but one must worry about the effect of a couple of years of good crops on the present scale of effort. Governments must keep the long run look in the center of their planning and "run scared" if we are to avoid future food disasters.

Reserves. But even if we avoid long-term price rises due to increased scarcity of grain as demand goes on rising, we still have to worry about what would happen in bad years. Globally, this requires reserves of grain over and above working stocks [discussed in more detail in another article below]. I prefer an international system of national government reserves with purchase and sale policy guided but not determined by regular consultations among the participants, hopefully the dozen countries who are the largest exporters and importers. There should be, however, some form of sanction against non-participants or flagrant violators of the general rules of the game. We are not making much progress in negotiating on this despite approval of this objective at the World Food Conference.

It is not unreasonable for farmers' organizations to wonder, as they have done rather vigorously at the highest political levels, if organized consumer power will not result in more effective control of high prices than low ones once a reserve stock has been created. There will always be disagreements between consumers and producers on what is a reasonable price when price stabilization policies are at issue. But in the case of food there are, I believe, valid reasons for insisting on a considerable degree of forced price stabilization, and a balanced program should not be impossible to achieve. The world needs rising output of food: ensuring that farmers get a return which justifies a maximum

productive effort by them is a must for U. S. consumers as well as malnourished Indians. But because there will be bad harvests, it is equally important to both groups that reserves be available to prevent prices going through the ceiling as they did a couple of years ago.

Food Aid. Measures to increase the self-sufficiency of developing countries and reduce their projected import needs will take time - the output from a new food production project is usually expected to reach its peak in about ten years. Meanwhile the poorer food-deficit countries will from time to time experience unusual shortages of grain or the foreign exchange to buy it. I believe that we must adopt a policy of ensuring that countries which find themselves in any year in desperate situations with respect to basic food supplies be able to count on priority attention from us in the U. S. That requires, as I see it, that if food grains are in short supply we can and do give preference in exports to those countries with the greatest need rather than those with the most money, and to those that need to import to feed people rather than to feed cattle. The present PL480 Legislation should be amended so that the Secretary of Agriculture is no longer required to certify that supplies exceed domestic demand and the commercial export possibilities before grain can be made available to food aid purchasers. With respect to food aid, we should take the lead but not try to act alone, urging others to share the opportunity to help; our food aid is given as a purchase order, not as a bushel of wheat, and any rich country can do the same even if it has no wheat to export.

Combatting Malnutrition. All these efforts to prevent scarcities from raising food prices beyond their costs will help prevent malnutrition from getting worse but do little to reduce it. I believe our governments must attack this problem from all possible angles. The same remedies should not be applied everywhere: more than most problems, this one is location-specific as to both the nature of the malnutrition and the most effective ways to correct it. However, the lack of income is central to most malnutrition.

Unfortunately the whole subject of nutrition has been given too little attention. Developing country governments which have incorporated nutrition considerations into their economic plans, let alone into effective programs, can be counted on the fingers of one hand. Donor organizations are in general not much better, except for USAID which has long been a pioneer. The World Bank this year approved its first project addressed solely to nutrition, one in the Northeast of Brazil. Hence the first task is to increase the awareness of the cost of present levels of malnutrition in holding back progress toward accepted goals of modernization and economic growth.

Beyond that, it is convenient to divide government actions into two sorts: those which primarily affect demand or capacity to pay for food, and those affecting supply or the price which must be paid. I do not expect early progress of any importance on the first. Even if general development can be speeded up, the record makes clear that in most

economies this will not by itself reduce the number of very poor and hence of the malnourished. Planning economic growth to do better must make progress against a 2-1/2 percent annual increase in the work force. Income redistribution is not very promising either: few political power structures are for it; it is bureaucratically difficult to operate; and there isn't in the poorer countries all that much income to redistribute.

We are, therefore, forced to look to the supply side for most of the progress we need so badly. Having covered major production issues above, there remains the improvement of the efficiency of the system moving food from the farmer's field to the consumers stomach. While results are apt to be slow with the best of effort, there are some real opportunities for improvement. But one must not sacrifice incentives to farmers to reduce consumers' costs; it must be done by increased cost-efficiency. (1) Research on new technologies must be expanded and addressed more specifically at cost-efficiency. (2) Investment on farms and in irrigation, roads, etc., must put cutting costs as its primary purpose. (3) Distribution costs between the farm and the consumer must be reduced. Cutting transport costs means not only better roads but growing food closer to the consumer. A vigorous attack on post-harvest waste must have full government support along with other storage problems. (4) Finally, governments must put a high priority on educating families, mostly the women, through all available channels on how to select, prepare and distribute nutritious food within the family and make available money go as far as possible. Eating habits are more open to change than many realize.

[Extracted from an Address by Edwin M. Martin to the American Dietetic Association, Boston, Massachusetts, October 12, 1976.]

Meeting Food Needs in the Developing World

International Food Policy
Research Institute

[A continuation of current trends in the production and consumption of staple foods to 1985 will mean a doubling of the import requirements of developing countries. This article reviews the situation for different regions and countries, indicating the main problem areas.]

This report is concerned with the food needs of more than half the people on earth--those who live in developing countries of Asia, Africa and Latin America which are classified as developing market economies (DME), as distinct from those in the People's Republic of China and other Asian centrally planned economies. By 1985, their numbers will exceed 2.5 billion people, of whom 2.2 billion may well be living in food deficit countries if production performance since 1960 is repeated in the next decade. For most, their present situation is precarious. It is likely to turn much more alarming unless actions are taken to forestall it.

Unless the trend of production in DME countries improves in future years the production of cereals, the major food in most developing countries, will fall short of meeting food demand in food deficit countries by 95-108 million tons in 1985/86, depending on the rate of economic growth. This compares with shortfalls of 45 million tons in the food crisis year, 1974/75, and an average of 28 million tons in the relatively good production period in 1969-71. Asia accounts for some 50 percent of the total projected deficits, North Africa/Middle East about 20 percent, Sub-Saharan Africa and

The International Food Policy Research Institute is a non-governmental research organization under multi-national direction, located in Washington, D.C.

Latin America about 15 percent each.

A total cereal deficit of about 100 million tons in DME food-deficit countries could well prove conservative. It is based on projecting the production trend of 1960-74, an average increase of 2.5 percent a year, to 1985. During the last half of that period, in 1967-74, the rate slowed to 1.7 percent. This is too short a period and with too much variation from year to year to serve as a reliable base for projecting the future. Nevertheless, the pervasiveness of the slackening in production for all regions and cereal crops (except for wheat in Asia, the most visible evidence of the "Green Revolution") suggests that it may well be difficult for DME food-deficit countries to maintain their longer term production trends. And if future performance reflects the more recent trend, cereal production could fall short by an additional 100 million tons, doubling the cereal deficit to about 200 million tons. The transfer of such a large amount of food, largely from developed countries, could well be unmanageable physically or financially.

Low Income Food Deficit Countries

The core of the food problem is in the low income food deficit countries (i.e., those with per capita incomes of less than $200) where 60 percent of DME population now live, and where most of the expected increase in population will come. They are projected to incur about half of the total DME deficit, some 42-48 million tons of cereal by 1985. The probable costs of financing imports of such magnitude would appear to be beyond any prospect of these countries having the foreign exchange to use for this purpose. The only feasible way for most of these countries to meet food demands--and the least costly over the long run--is to increase their own production more rapidly. It would require increasing the production growth rate from 2 percent a year to almost 4 percent. To approach this goal would require very substantial increases in investment in resources devoted to food production and greatly improved agricultural performance in the countries concerned. This will not be possible without heavy transfers of capital and technology from developed countries. Even if these could be assured, it would be unrealistic to look for the aggregate growth rate to move rapidly from 2 percent a year to 4 percent, considering that agricultural development is a slow and difficult process and the inevitable lags that occur before investments begin to produce. In the meantime, it is clear that there will be need for food aid from the developed world, very likely in larger amounts than heretofore, to help feed these people.

Unless such inputs of capital, technology and food aid are forthcoming, the inevitable result would be a further decline in per capita consumption, either by higher prices or by rationing. Most countries in this category already have average diets which fall below minimum adequate energy levels. Even if the projected consumption levels for 1985/86 were to be

attained, they would allow for only 2-4 percent improvement over the 1969-71 per capita levels. Further, inasmuch as projected consumption levels generally reflect market demand, the number or proportion of malnourished people is not likely to be reduced unless there is major restructuring of incomes or other means of redistributing the food supply. This group of countries contains the bulk of the malnourished in the developing world, estimated by FAO to total some 440 million people in 1970. The principal problem countries or groups, as indicated by figures that come out of the projections, are:

	Cereal Deficit 1974/75 (million tons)	Cereal Deficit Projected 1985/86 (million tons)
India	6.7	14 - 17
Bangladesh	2.3	5.0 - 5.5
Indonesia	1.1	7.5 - 9.5*
Nigeria	0.3	6.5 - 7.0*
Sub-Sahara Low Income Group	1.2	3.5 - 4.5*
	11.6	36.5 - 43.5

* In the case of Indonesia, if the 1967-74 production trend should prevail, the deficit would largely be eliminated. The deficits for Indonesia, Nigeria, and Sub-Sahara low income countries take into account the projected supply of root crops as an alternate source of calories (see below).

High Income Countries. This group is defined as having enough capacity to generate foreign exchange to meet food demands by imports. It contains 8 percent of the DME population, and includes the North Africa/Middle East OPEC countries, Venezuela, and high growth countries in Asia such as Taiwan and South Korea. They now import about one-third of cereal requirements. By 1985/86 they may be importing two-thirds of their requirements. This group represents a large and expanding commercial market for 30-35 million tons of cereals by 1985/86.

	Cereal Deficit 1974/75 (million tons)	Cereal Deficit Projected 1985/86 (million tons)
Asia High Income Group	6.7	17 - 20
NA /ME OPEC Group	4.8	11 - 12
Venezuela	1.5	2 - 3
	13.0	30 - 35

Middle Income Food Deficit Countries. Countries in this middle group contain about 20 percent of DME population. The average production rate for cereals has been much more satisfactory, increasing about 3 percent per year, but it has not kept up with the demand for cereals in which feed is of increasing importance. A rate of over 5 percent a year would be required to meet cereal market demand. The total deficit is projected to rise from 17 million tons in 1974/75 to 23-25 million tons by 1985; but Mexico's deficit is likely to decrease and Egypt's, although sizeable, to remain about the same as in 1974/75. This group represents a mixture of countries, some likely to be able to import commercially and others requiring some concessional food aid. While the needs of some are somewhat less urgent than for others, there is need in most countries for additional investment in food production.

Certain problem areas stand out.

	Cereal Deficit 1974/75 (million tons)	Cereal Deficit Projected 1985/86 (million tons)
Sub-Sahara Higher Income Group (above $200 per cap)	0.6	2
Mid America/Caribbean (other than Mexico)	2.9	4.25 - 4.5
Latin America (except Argentina, Brazil and OPEC countries)	2.3	5.25 - 5.5
Egypt	3.5	3.5
	9.3	15.0 - 15.5

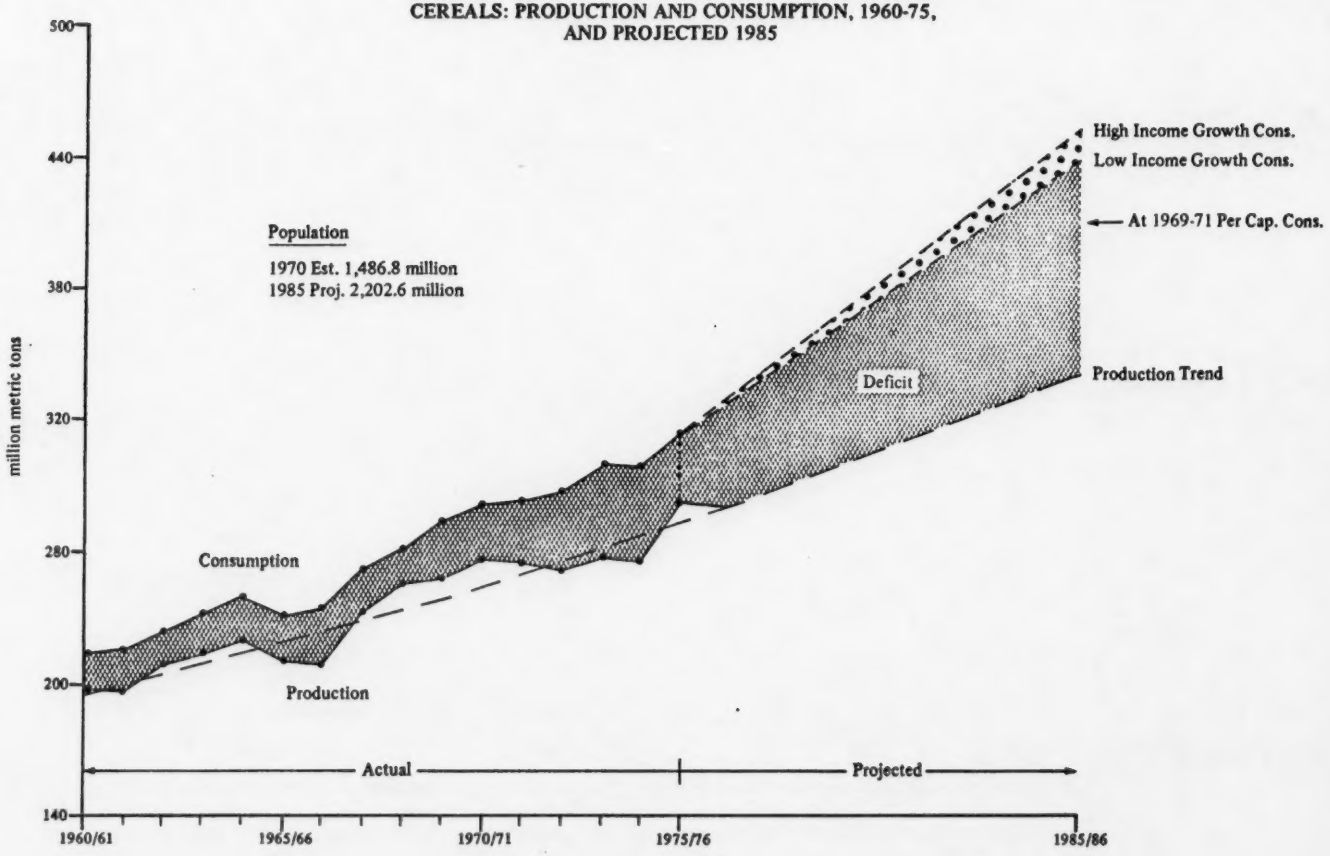
Cereal Exporting Countries. Only Argentina and Thailand among DME countries are currently major cereal exporters. If historical growth trends persist, Brazil and Pakistan, presently in deficit, will move to an export position as well. This group with 13 percent of DME population, has more than enough to feed its people. Whereas DME cereal exports have been about 10 million tons in recent years, the projection of exportable supplies in 1985/86 is in the range of 25-30 million tons. Their export surplus will represent a small part of the world supply of cereals available to purchasers in deficit countries.

People's Republic of China. At the historial production growth rate of 3.4 percent a year and population growth of 1.5 percent a year, China appears to have the capacity to become a major cereal exporter in the 1980's if that should be its governmental policy decision. However, the more likely route would be toward improving the diet of its people and meeting the deficits of other Asian centrally planned economies. For these latter, production is falling significantly behind population growth.

FIGURE 1

ALL FOOD DEFICIT DEVELOPING MARKET ECONOMIES*

CEREALS: PRODUCTION AND CONSUMPTION, 1960-75, AND PROJECTED 1985



Root Crops in Relation to Cereal Deficits. In a number of countries root crops make up an important part of the diet and are a competitive source of calories with cereals. In a band of countries across the center of Africa, stretching along the west coast from Guinea on the north to Angola on the south and eastward through Zaire and Tanzania, cassava, yams, and sweet potatoes provide about as much calories as cereals. In Latin America, a band from Brazil to the west coast, cassava, potatoes, and plantain provide half as much calories as cereals. In Indonesia, cassava provides one-third as much. Thus, future trends related to root crops affect cereal requirements.

Wide discrepancies are apparent between the production estimates of root crops of FAO and those published by U. S. D. A. The latter, expressed in terms of wheat equivalent in calories, have been used in this report. Assuming that the production trend of the past decade will continue and that per capita consumption of root crops in 1969-71 will, on average, remain the same (i. e., zero income elasticity), rough calculations have been made as to the increase or reduction that would be involved in the cereal deficit in 1985/86. The assumption implies that increases in per capita income will be reflected more in demand for cereals with their higher energy and protein content rather than for root crops. Thus, in countries where production of root crops is not keeping up with population growth the cereal deficit is increased, and where production of root crops is rising faster the deficit is decreased.

Sub-Sahara Africa	
Nigeria	1.1 million tons decrease in cereal deficit
Other Low Income Countries	0.4 million tons decrease in cereal deficit
High Income Countries	0.5 million tons decrease in cereal deficit
Latin America	
Brazil	2.0 million tons increase in cereal surplus
Ecuador	0.1 million tons decrease in cereal deficit
Other Latin America	0.2 million tons increase in cereal deficit
Asia	
Indonesia	0.9 million tons increase in cereal deficit

In total, these shifts would hardly change the total gross deficit. The surplus in Brazil would be reflected in larger exports of cereals. The cereal deficit for Nigeria would be reduced by more than a million tons, whereas that for Indonesia would be increased by almost the same amount.

[Extracted from Meeting Food Needs in the Developing World, Research Report No. 1, published by the International Food Policy Research Institute, Washington, D. C., February 1976, pp. 1-5, 13, 19.]

Food Aid: Its Potential Disincentives to Agriculture

Paul J. Isenman and Hans W. Singer

[International aid in the form of food has been coming under criticism in recent years for having a negative impact on farm production and on policies in support of agriculture in recipient countries. While such disincentive risks must be taken seriously, they have often been exaggerated and inadequate attention given to ways of offsetting them.]

Food can be considered one of the world's most vital natural resources. In the interests of mankind as a whole, access to the scarce resources vital for a country's existence should be more equitably shared and should not depend only on market allocation according to current purchasing power. In the case of food, demands for animal feeds bid away land, fertilizer, and even grains from the needs of poor people for grains themselves. The poorest countries need special help in the circumstances created by the rise in oil prices. Food aid appears to be an obvious mechanism by which scarce and vital supplies can be allocated outside the normal market mechanism to help meet basic human needs.

However, there is general agreement that the long-run answer to food shortages in the poor countries must be sought in expanded food production in these countries themselves, and in employment and income distribution policies which provide sufficient incomes for the poor to be able to buy enough food. There is sufficient concern about the possible harmful effects

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of food aid on domestic food production that many economists oppose food aid (other than, perhaps, for emergencies), even in the countries where nutritional and other human needs are strongest. It is the purpose of this article to review some of the analytic issues relevant to this concern about the disincentive effects and risks of food aid, which we have found to be strongly held by agricultural economists and aid practitioners. Reference will be made to the experience of food aid in India, not because India is at all a typical recipient of food aid, but because it received the largest share (up to 1971) and is most often cited as the prime example for negative effects of food aid.

Briefly, the disincentive argument is that the increase in food supplies provided by food aid depresses the prices received by farmers, and causes or supports inadequate agricultural policies by recipient country governments; both these effects lead to decreases in food production. The recent stress on the need for employment and more equal income distribution, with its attendant stress on agriculture and rural development, has served to sharpen the criticism of food aid which is said to interfere with these objectives.

On the other hand, it is surprising how many recent studies and policy discussions either dismiss or miss entirely the direct purposes of food aid, as if it were to be judged solely on the basis of its contribution to food production. It is worth briefly reviewing what these purposes are: First, food aid provides food for the hungry, both by direct subsidized distribution, often concentrated on nutritionally vulnerable groups such as children, and by helping to contain price increases, which tend to hit the nutritionally vulnerable groups the hardest. Second, it provides financing for specific government development projects, some in agriculture and rural development and some in other sectors. This could be done either directly, as in "food-for-work" projects, or indirectly as in the Pakistan rural public works program. Third, it can be used to build up food stocks which, while quite expensive, can contribute to both consumer and producer welfare by reducing price fluctuation and uncertainties. Fourth, it eases a major constraint on growth in overall output and employment.

The fourth, which is quite important, often tends to be neglected. In lower-income densely-populated countries food, along with foreign exchange, tend to be the major constraints on the pace of development. Two-thirds or even more of workers' incomes go for food in these countries, most of it for food grains. From a Finance or Planning Minister's point of view, any proposed increments to public or private employment, through fiscal or monetary policy, must be measured against available food supplies; it is almost as if the whole economy consisted of a public sector food-for-work program in which all workers were paid two-thirds of their wages in food. So not only does food aid permit recipients to expand employment, but the high proportion of workers' incomes which go for food grains means that farm prices need not suffer from food aid in the longer run because of dynamic effects on national savings and income. In explaining the purpose of food aid in India, Rath and Patwardhan (1967) say: "Food grains were vital to the success of the plans of economic

development which India had launched . . . The purpose of PL 480 imports was not only to prevent . . . sharp fluctuations in price of cereals, but also to check any excess pressure of the general inflationary forces on prices of cereals, which might arise due to the slower rate of increase in production of cereals than of other commodities in the economy."

Food aid is a special form of assistance tied to a specific set of commodities, and often it is further limited to specific internal uses. For this reason it may be less valuable to the recipients in carrying out their development strategy than an equal amount of aid not so restricted - unless the commodities imported and specified domestic uses correspond to what the recipient would have done with unrestricted aid. Relatively unrestricted forms of financial aid would be preferable, to let the recipient choose the best balance between food and non-food imports. However, what makes food aid a subject worth special consideration is that it is partly "additional", that is, it often is made available by donors as an addition to other kinds of aid. Food aid is unlikely to be as fully additional as it was in the past, when the U. S. and other donor nations had large long-term surpluses built up because of domestic agricultural policies. But there are still a number of factors which make food aid likely to remain at least partly additional. These include a feeling among the general public and legislatures in donor countries that feeding the destitute, avoiding starvation, and improving the nutritional standards in developing countries should have priority as a form of development cooperation. The political importance of farmers, who benefit from the increased demand caused by food aid, also adds to the political attractiveness of food aid. Thus, there is likely to be some domestic political support for food aid in donor countries even when there are no overall surpluses, and it is also quite likely that there will continue to be periodic surpluses.

Effects of Food Aid on Agricultural Production

Price Effects. To evaluate the net effect of food aid on domestic food production we need to consider its effects on the price of food. This depends on several factors: the amount of food aid to be provided in relation to total production; the additional demand for food in the period to be considered, whether it is created through specific projects, by programs such as subsidized food distribution, or is the result of increased private sector activity supported by fiscal or monetary expansion; the expected changes in relevant crop and input prices; the relationship of the foregoing to food prices (using the price elasticity of demand); and the effect of the resultant change in food prices on food production (using the price elasticity of supply). It is preferable to estimate these effects through a multi-equation econometric model, since some of the independent variables affecting food production and

demand also affect each other over time. However, this is easier said than done: the problems include the time and expense involved in country studies; the lack in many countries of reliable data for relevant variables; the danger of leaving out or mis-specifying relevant variables or relationships (as indicated below); and changes in agricultural technologies, or in government policies such as price supports, which reduce the validity of conclusions drawn from analyses of past data. These problems do not disappear when a "common-sense" approach, based on qualitative and rough quantitative analysis of a few variables, is used instead. But in some circumstances a "common-sense" approach does provide a feasible way to handle some of these problems and to allow for political and other factors difficult to include in precisely articulated models.

The evidence that price is important to agricultural production - that farmers respond positively to price incentives - is by now well known and convincing. Thus, any significant price declines caused by food aid must be taken seriously. However, to say that prices need to be high enough to provide strong incentives for increased production is not to say that "higher is always better", or that price is necessarily the key constraint on output in a given situation. While the supply response to price changes is generally positive, it tends to be quite low, between 0.1 and 0.2 in land-scarce countries, because of the relatively inelastic supply of land and the consequent diminishing returns to other inputs. The price elasticities of supply for crops in a given country will change, for example, with a shift in technology (depending on responsiveness to fertilizer and other inputs) or with shifts in other constraints on production such as the timely availability of inputs.

One must balance the needs of actual and potentially producing farmers against those of consumers, and against any effects of rapid food price increases on income distribution which may appear detrimental (e.g. if large farmers provide most of the marketed surplus of food grains). In some countries, there is an economically and politically valid case to be made for government distribution programs to ameliorate shortages in the cities and, at the very least, to prevent starvation in the countryside in bad years. But in these countries there are usually severe political constraints on the budgetary resources which could be tapped for food distribution programs, particularly in shortage years. Some of the literature on food aid and pricing policy is somewhat cavalier in recommending something quite close to a generalized price maximization, with little consideration of how much or little will be the likely increase in output (price elasticity of supply) or the likely human and economic costs in other spheres. In some circumstances, higher food prices may not be desirable. We strongly favor incentive prices to farmers as a general proposition, and believe that in developing countries farm prices have tended to be too low; but we would argue for the careful analysis of particular price situations, as against the rigid price "fundamentalism" that one sometimes encounters.

In Table 1 we review some of the data bearing on the price and production effects of food aid on food grain production in India. To summarize (regrettably omitting desirable explanations and qualifications),

Table 1. Data on the Effects of Food Aid in India

(Millions of Metric Tons)

	Net food-grain Imports	US "Title 1" Food Aid	Gross Domestic Production of Foodgrains	Net Imports as % Net Production	Government Distribution of Foodgrains	Foodgrain supply per person per day (ounces)	Relative Price of Foodgrains	Industrial Production Growth (%)
	1	2	3	4	5	6	7	8
1955	.5	-	70.7	1	1.6	14.8	92	8
1956	1.4	0.2	69.3	2	2.1	15.2	103	8
1957	3.6	2.7	72.5	6	3.1	15.8	105	3
1958	3.2	2.0	66.6	6	4.0	14.4	109	2
1959	3.9	3.2	78.8	6	5.2	16.5	101	8
1960	5.1	4.3	77.1	8	4.9	15.8	95	11
1961	3.5	2.3	82.3	5	5.0	16.5	93	9
1962	3.6	2.9	82.4	5	4.4	16.4	97	10
1963	4.5	4.2	80.3	6	5.2	15.7	100	8
1964	6.3	5.4	80.7	9	8.7	16.0	109	9
1965	7.4	6.4	89.4	10	10.1	17.0	105	9
1966	10.3	8.1	72.3	16	14.1	14.4	109	0
1967	8.7	6.0	74.2	13	13.2	14.2	122	0
1968	5.7	4.2	95.1	7	10.2	16.3	111	7
1969	3.8	2.6	94.0	5	9.4	15.7	115	8
1970	3.6	2.5	99.5	6	8.8	16.1	108	3
1971	2.0	1.2	108.4	9	7.8	16.6	108	3

we found that food aid did cause a decline in relative food grain prices, but only during a fairly short part (1960-62) of the food aid period from 1956 to 1971. The supply of food grains appeared to be responsive to price changes, but not strongly: the price elasticity of supply was about 0.15. The depressing effect of food aid on prices was much less than some analysts had expected, partly because the aid was used to increase government food distribution which, being subsidized, added to net food grain demand. For example, J. S. Mann (1968) estimated that food aid had resulted in a decrease in food production by about one third the amount of the aid. The most comprehensive available study (by Rogers, Srivastava and Heady in 1972) found the net loss in domestic production to be only 3 percent of the food aid provided. The results of their multi-equation model appear to be consistent with our much less sophisticated look at the weather-corrected output data for the period of

low relative food grain prices. Even the elaborate study by Rogers et al ignored the dynamic indirect effect of the food aid on the rate of growth in national output and employment and, hence, on the demand for food grains in subsequent periods. Food aid appears to have played a major supply and "insurance" role in the investment and output boom of the first half of the 1960's, which was important in itself and which also generated substantial increases in food grain demand. We conclude that large-scale food aid should have been phased in more gradually in some years, by stockpiling more and distributing less; nevertheless, the short-term price effect on food production was very limited. The medium-term income and price effect on food production, taking account of the effect on overall output, employment and nutrition (as distinct from food grain production only) was strongly positive.

This is not to say that in other countries and different circumstances food aid has not had a significant price disincentive effect on domestic production. For example, a recent article by Dudley and Sandilands (1975) discusses the rather extreme case of Colombia, where wheat imported under food aid and also from commercial sources (at a subsidized price because of an overvalued exchange rate) rose from about 50 percent to about 90 percent of total wheat consumption from 1953 to 1971. There was a government support price for wheat, but it declined by about half (in constant prices) over this period. Wheat production, concentrated in high-cost production areas, declined very sharply to about a third of its initial level. We have a number of questions about the analysis and interpretation in this study (since food aid accounted for only about one third of total wheat imports, the title "The Side Effects of Foreign (Food) Aid" is somewhat misleading). But one cannot question the basic relationship between wheat imports, farm prices and production.

Policy Effects Attributable to Food Aid. Even if food aid does not have a significant disincentive effect on food prices, it could still have a significant "disincentive effect" on the overall agricultural policies of the recipient government. The idea here is that if a government is enabled to supply its country's needs without efforts to improve its own production, it will have less incentive to undertake such efforts. This might be apparent as a relative neglect of agriculture compared to other sectors; as a continuation of policies which did not provide adequate encouragement or support to farmers; as unwillingness to take politically difficult steps which may be thought necessary to raise output in the larger run. In India, although a good deal of money and policy effort was expended on agriculture, there can be little disagreement that the strategy of the Second and Third Indian Five-Year Plans (1955-65) was focused on import-substituting industry, particularly heavy industry. Food aid supported and facilitated this strategy, particularly by enabling the Indian government to maintain large sub-

sidized distribution programs, while in the eyes of many analysts some basic questions of food grain production and distribution were ignored.

However, one should distinguish between the policy effects of aid and policies supported by aid but caused by political and economic factors far more powerful than aid. One must consider whether a reduction or withdrawal of the food aid would have changed the "erroneous" strategy, or would merely have made its implementation less efficient and slowed development. There are also questions, arising in donor as well as recipient countries, about the proper role of donors and about their influence on questions of basic development strategies, and whether governments respond more constructively to the "stick" than to the "carrot". In the Indian case, the evidence is clear that the political and economic factors which caused the preference for heavy industry over agriculture were far more powerful than the influence of food aid which, at most, played a supportive role. In the eyes of Indian political leaders (and many outside India) the association of industrialization with such things as modernity, greater political and military independence, increases in savings rates and improvements in human capital, combined with an uncertainty as to how Indian agriculture could best be developed and whether food supply was meaningfully responsive to price incentives - all these greatly overshadowed the role of food aid in the formulation of Indian economic strategy. In our judgment, had there been much less food aid, growth in government expenditure and in non-agricultural output and employment would clearly have been lower, but the basic strategy would not have been changed.

Up to 1965, however, food aid may well have had some negative effect on particular steps which might have been taken within the overall Indian development strategy to strengthen agriculture - for instance, by reducing the pressure to keep up adequate supplies of imported fertilizer. But if food aid had caused farm prices to decline and less fertilizer to be imported, the effect of the fertilizer shortage should have been an increase in the observed price elasticity of food supply. As we saw, the short run effect on domestic production was apparently small. The effect of food aid on the government's agriculture budget was probably positive, because of its direct and indirect growth-inducing effects on government revenue and development expenditures.

After two successive serious droughts in 1965 and 1966, there was a reorientation of priorities towards agriculture; this shift was assisted by a growing disillusionment about the primacy of heavy industry in the development process, by the availability of the new high-yielding wheat varieties, and by food aid. During the period of severe shortage, food aid provided sufficient security for the government's "buffer stock" and distribution programs so that the risk of eliminating the disincentive-causing restrictions on grain marketing in surplus areas, which had been imposed to enable the government to buy cheaper grain for subsidized distribution programs, was greatly reduced. In addition, the

agreements for American food aid contained a number of commitments by the Indian government for expansion and improvement of particular agricultural programs. There was, however, a great deal of political resentment within India about U. S. food aid, partly because dependence on the U. S. for food appeared to undermine India's political and economic autonomy and its sense of self-reliance, and partly because of President Johnson's "short-tether" policy, under which much needed food aid shipments were delayed in order to put pressure on India. During the late 1960s, there were redoubled efforts to emphasize and encourage agriculture, with a goal of dispensing with food aid. This goal was substantially achieved in 1972; and although reverses in production since then have meant that India is still far from self-sufficient in food grains, aid has remained well below its earlier levels.

This simplified summary of Indian experience serves as an illustrative backdrop for several general points. Food aid can be used to support both "good" and "bad" agricultural policies. It would be quite unrealistic for either critics or proponents of food aid to take it for granted that this aid is a major or determining cause of such policies. If a country has a strong commitment to agriculture and the political will and sound policies to carry out that commitment, then it is likely to use the food aid in a way that supports its agricultural development effort. If there is no such commitment, then food aid will be used to further whatever objectives the government does pursue. There are steps that donors can take to foresee and prevent the likely effects of food aid in supplying marginal disincentives to "good" policy. The first step should be a case by case analysis of the situation and policies of major recipients of food aid: problems, and their feasible solutions, will vary considerably among countries and within countries over time. Fortunately, the thinking among both recipients and donors on the role of agricultural development has changed a good deal since the period a decade ago on which much of the current criticisms of "disincentive effects" are based. Also, the sparseness of the world food supply during 1973/1974 has made recipient countries well aware that they cannot count on large scale food aid in times of shortage, but must rely instead on their own food production if they are to avoid costly commercial food imports. Disincentive effects are thus becoming less probable.

Project vs. Program Assistance: Tying Food Aid to Selected Projects

We use the term "project assistance" to cover all situations where the donor's aid is tied to specified activities. This specification may be done either through provision of food to go into particular projects as in a "food-for-work" program, or through agreement for the uses of "counterpart" funds generated by the recipient government's sales of the food received from food aid. Food aid in "program" form, meaning that the recipient government may distribute or sell the food and use the proceeds as it wishes, can in principle make a more ef-

fective contribution to the recipient's development objectives than aid tied to projects which the recipient country would not otherwise have undertaken. For example, problems and inefficiencies can occur when donors support projects which cause distortions in a recipient's development plans, or which are unlikely to be continued by the recipient when the aid for that project is phased out.

Such general principles must, of course, be tempered to take account of the complexities of the real world. In some circumstances, where a donor lacks confidence in a recipient's overall agricultural policies, channelling food aid through specific projects may help address policy-disincentive problems. Some governments may welcome, or at least not object to, receiving food aid in project form; for example, officials in a receiving country bureaucracy may find useful the donor support for project they think valuable but which would otherwise be difficult to fund. Projects specified in food aid agreements may offer a way for both recipients and donors to assure that the benefits are directed toward specific disadvantaged groups, as one instance. Food aid in project form can be particularly helpful where it is desired to direct the food aid to support of agricultural production. The food aid may be used, for example, to build up food stocks; as part of a plan to expand the overall agriculture budget with counter-part funds; or to support labor-intensive rural infrastructure projects, as in the food-for-work programs in several countries.

Implications for Food Aid Allocations

The probability of world market shortages and high prices of food in many future years, in comparison with the general surplus situation in the 1960s, means that donors need to be increasingly concerned about the allocation of food aid. Where food aid is considered likely to have a significant disincentive effect which cannot be eliminated - generally where overall agricultural policies are considered to be weak - donors should adjust the mix between food aid and non-food aid or, if necessary, cut back on food aid without offsetting increases in other aid. There are several reasons, however, why donors should be cautious in emphasizing agricultural "performance" criteria in the allocation process. First, to go as far as adjusting every annual allocation on the basis of "performance" would cause friction in the political relations between donor and recipient (as with other donor attempts to use "leverage" to force major policy changes), and might either not work to produce the desired policy results or even backfire and have the opposite effect. Second, donor judgments may be incorrect. Such judgments tend to change over time. Third, an overly tough, restrictive approach to the distribution of food would conflict with what should be the underlying allocation criteria for food aid such as poverty, shortage of food, and shortage of foreign exchange to import food commercially. It would be unfortunate if the use of "performance" criteria were inadver-

tently to introduce a bias towards helping countries which, on the basis of income and food availability, needed it the least. Thus, a moderate standard of "performance" in efforts to raise food production should be considered as a condition for receiving food aid (other than that directed to disaster relief) but not as a substitute for other allocation criteria.

A recipient's ability to develop good food aid projects should not per se be a significant criterion of inter-country allocations, since higher income countries tend to be more skilled at project design and presentation. Preference should be given, in allocation of the aid and especially of donor assistance in project preparation, to countries with low income and food shortages. Nevertheless, serious attention should be paid to project design and appraisal. For example, a repetition of past donor-funded projects which provided cereal grains for subsidized animal feeds, used to produce foods primarily for high income consumers, should be avoided. One further aspect needing attention in the allocation process is to be particularly sensitive to potential conflicts between development objectives and other objectives of food aid, whether commercial, political or even humanitarian. The stronger the emphasis on non-development objectives, the more risk there is that conflicts with recipient countries' production incentives will arise and that insufficient attention will be paid to them.

We have seen that the disincentive risk of food aid is more complex, more easily avoided, and more limited in effect than some analyses have suggested. Even where there is an observed or likely disincentive effect, food aid should not necessarily be reduced until its costs as a disincentive are weighed against its employment, nutritional, export or other benefits. Food production is so important that very heavy weight should be given to the disincentive issue; but to ask only "is there a risk of a disincentive effect?" is to consider any drop in food production to be an infinite cost and to ignore other benefits entirely. It would be unfortunate if the benefits of advantageous use of food aid were to be lost because donors and recipients did not undertake the available means for anticipating and offsetting the disincentive effects.

[Adapted from "Food Aid: Disincentive Effects and their Policy Implications," Economic Development and Cultural Change, Vol. 25, No. 2, January 1977, p. 205. Copyright © The University of Chicago.]

Kicking the Wheat Habit

Dr. Omawale

[The present reliance on wheat products as a food staple in the Caribbean islands means dependence on a product which cannot be grown locally and must be imported. The possible ways out of this undesirable situation are explored.]

The diets of nearly every people revolve around one particular food, or small group of foods. Often they are cereals: rice in the Far East, wheat in the Near East, maize in Latin America, millets in the African savannahs. They may also be roots or starchy fruits: cassava or yams in West and Central Africa, the sweet potato in the Pacific, and plaintains or bananas in East Africa. These are the staples, and they supply the bulk of a people's energy (calories) and protein.

Acting in a logical fashion, a society would choose its staple food on the basis of hard ecological and economic criteria. Wheat, for example, does not grow well in the tropics; it must be imported at a considerable expense. So wheat is obviously a staple for the temperate regions. The root crop cassava, on the other hand, is indigenous to the tropics. But the societies do not always make their choices on the basis of logic. For example, the peoples of the English-speaking Caribbean acquired the practice of eating wheat during the colonial encounter. Wheat bread had social status. It was the proper, civilized thing to eat. Unfortunately, however, nobody thought to develop the agricultural methods needed to grow it under local climatic conditions.

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So in the Caribbean today, the favored staple is wheat. In the form of bread and biscuits, it contributes as much as 26 percent of the dietary energy and 31 percent of the protein in parts of the Caribbean. At the same time, these wheat imports in 1975 amounted to over US$44 million for a population of less than 5 million. With a per capita income of about $656, the peoples of the Caribbean can ill afford such a luxury. The economic, and ultimately the social and nutritional consequences, are very great.

The search is on for a staple to substitute for wheat that can be grown in the Caribbean, and at the same time be nutritionally and socially acceptable. With the cooperation of the Pan American Health Organization (PAHO, a regional branch of the UN World Health Organization), the region's governments are developing food and nutrition policies that deal with this concern. PAHO's Caribbean Food and Nutrition Institute and the region's governments have already made surveys of the diet composition of a number of territories. CFNI has also initiated a useful debate about nutritional issues related to wheat substitution, and some countries are already implementing programs.

The food crops which hold promise as replacements for wheat in the Caribbean include rice, cassava, sweet potato, yam, plantain or banana, dasheen (a root crop originating in the Pacific islands, also called taro), and tania (another kind of taro). Both rice and bananas are well developed export crops grown on a large scale with ample inputs, such as fertilizers. Guyana, for example, considers its rice exports an important earner of foreign exchange. These crops are therefore unlikely to make a major contribution for domestic wheat replacement in the near future. This is somewhat unfortunate since rice happens to be one of the best substitutes for wheat in bread making.

In Trinidad, a vigorous research program at the University of the West Indies has determined that with mechanization and proper extension programs, the productivity of sweet potatoes and yams could be greatly increased. Some varieties of these root crops already have high consumer acceptance, giving them good prospects for wheat substitution. In Guyana, cassava, now grown mainly by the poor subsistence farmers, has been selected as the most promising candidate for a wheat substitute. For one thing its productivity is high. For another, cassava can tolerate environmental extremes, and keeps producing even if relatively neglected. It does not require expensive drainage or irrigation. Therefore, cassava has traditionally been the crop of the small subsistence farmers. Large numbers of these same farmers could remain the producers of a much larger crop in the future. They would send their cassava to a few locally sited mills, avoiding in this way the large-scale, highly mechanized cultivation which is impossible for them.

As nutritious as wheat?

People still have their doubts. Will a wheat substitute be less nutritious?

Would its adoption mean giving up traditional baked goods? Will it really be sufficiently inexpensive?

Nutrition is unlikely to suffer. The major nutritional problem in the Caribbean is energy (calorie) deficiency, which results from insufficient food intake. Protein deficiency is often present as well, but would disappear if the same food were eaten in quantities large enough to satisfy the energy requirements. Moreover, if energy is needed, and proteins are available, the proteins will probably be used preferentially to provide it. Scarce proteins have therefore been used to do what cheap calories could have done.

Instead of worrying primarily about proteins in a diet, it would be better to strive for a balance between protein and energy. We should enable people to grow or buy enough food to satisfy their energy requirements: this will go a long way towards solving the protein problem. Recent work has shown that foods like rice, yams, and some varieties of sweet potatoes, which are not generally considered protein foods, have

HOW MUCH PROTEIN?

BREAD COMPOSITION	PROPORTION	PROTEIN CONTENT	NET PROTEIN UTILIZATION
wheat flour (white)	100	11%	37%
wheat/rice	70/30	10%	41%
wheat/rice/soya	70/27/3	11%	46%
wheat/rice/soya	70/25/5	12%	45%
cassava/soya	80/20	11%	55%

Source: "The Use of Soyflour in Composite Flours," de Reuiter, D.; Institute for Cereals, Flour and Bread TNO, Wageningen, The Netherlands (unpublished).

a balance of protein and energy good enough to satisfy human protein requirements if eaten in quantities that satisfy energy needs. Infants and people recovering from illness, who need more protein than others, could receive additions of small quantities of legumes which are sufficient to produce considerable increases in the protein available in these foods. Bananas and cassava, which are quite low in protein, would be suitable for composite flours. Calculations in Guyana suggest that even wheat flour consisting of 10 percent of cassava has an acceptable balance of protein and energy. Even more cassava could be substituted if a legume like soya bean or black-eye pea is included in the composite flour (see table.)

As cheap as wheat?

When retail prices alone are considered, some possible wheat substitutes, such as root crops, may at first glance appear expensive in the Caribbean. During the last quarter of 1975, subsidized wheat flour was the cheapest source of calories in 11 Caribbean countries; cornmeal was the cheapest in three islands, while cassava flour, green bananas and breadfruit were the least expensive in one country each. But as indicated, wheat is subsidized in the Caribbean; the government funds being used to keep the price artificially low could be better spent on much needed development programs. In addition, the present prices have little relation to potential for the future, and the future is quite important in food and nutrition planning. At present, for example, rice in Guyana typically produces 266 kilocalories per G$ per day (1 G$ = .4US$), while cassava yields only about 32. But rice - as well as that other important cereal, maize - is already highly bred and developed. On the other hand, recent trials with new cassava varieties have shown that productivity could increase five to seven times over the old varieties, even when grown with traditional technology on poor soil. Cassava, therefore, has considerable development potential; it can be much cheaper in the future than it is now.

Some people in the Caribbean advocate highly mechanized staple production in order to replace wheat quickly and economically. But such a policy could well be labor displacing, or at any rate not labor absorbing. We must pay close attention to the social consequences of wheat substitution. Programs causing the big farmers to grow richer at the expense of the small farmers must be avoided. In the Caribbean the poor have traditionally grown root and other food crops, as opposed to the export cash crops like sugarcane and rice. Given credit, intermediate forms of technology, and other extension services, this group would not only increase production and productivity, but also earn higher incomes that would lead to nutritional improvement. Moreover, their surplus labor would be put to work.

During 1976, Guyana is attempting to bring into cultivation an additional 600 acres of land each month for the production of cassava flour. Small farmers are encouraged and enabled to participate in this program by providing them with free planting material, credits for clearing and cultivating the land, and a guaranteed market for the produce. Mills are being set up in rural centers near the production areas, and the cassava roots are expected to provide flour for 10 percent wheat substitution, in addition to waste products that could be converted into animal feed. In the meantime, tests are proceeding to determine how satisfactory food products can be made. These include noodles, which have not as yet been tested, and the whole range of other traditional products like roti, dumplings and cakes.

Will people accept a substitute?

It is true that "old habits die hard." The consumption of wheat products is one such habit in the Caribbean: almost every meal or snack includes wheat. Fortunately, many composite flours can make bread, pasta and pastry products quite similar to the traditional wheat commodities. In Trinidad, a blend of four parts of wheat to one part of sweet potato went totally undetected by bread consumers. At a seven to three ratio, only a very small number could tell it was not pure wheat bread. Wheat-cassava blends at four to one have also proven successful for cakes in Guyana. Bread from the same mixture has a slightly different taste from plain wheat bread, though it is not unpleasant. But this bread did tend to stale rapidly, developing a sour smell and taste within 48 hours after storage in plastic bags. It has been shown in other countries that small quantities of preservatives could solve this problem.

If the wheat substitutes exceed 30 percent in a composite flour, as is contemplated, changes in baking technology will be required. The industry will have ample time to make the necessary adjustments, since large-scale production of the substitute crop will probably take a number of years. For example, a 10 percent substitution of wheat imported by Guyana in 1975 would have required 23,000 metric tons of cassava, but the total 1973 cassava production amounted to a mere 14,000 metric tons.

In the absence of a colonial experience, the Caribbean would have developed an indigenous staple with suitable products and appropriate technology. Why not break with the past now, and develop such products and technology, suppressing our longing for wheat products? Why not raise our social and political consciousness, and subordinate personal wants to social needs? Development certainly cannot proceed rapidly in the Caribbean while badly needed foreign exchange is spent on nonessential food imports. In the final analysis there is no option for the Caribbean. Foreign exchange must be spent on essential capital equipment to speed the process of development. Food for the region can and must be produced largely within the region.

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Rebuilding Grain Reserves

Philip H. Tresize

[The world's stocks of grain have been sharply depleted in the 1970s, and repetitions of the 1972/73 shortages and price rises are predictable if reserve stocks are not rebuilt. This article examines the scale of the problem and a number of the issues involved.]

During the 1965/66 marketing year world stocks of wheat and coarse grains were reduced by some 35 million tons, or 25 percent, because of a short grain crop in the USSR and a threatened famine in India. In 1972/73 the stocks fell again by almost 30 percent, or 44 million tons, mainly because of unusually large imports by the Soviet Union. The observable effect on prices and world trade in the first instance was nominal. But in the second, prices rose dramatically, food aid to the poor countries was cut back, and normal patterns of world trade were threatened with disruption. The state of world grain reserves during each of these two periods was a principal factor. At the outset of the 1965/66 marketing year world stocks amounted to almost 26 percent of the preceding year's wheat consumption and 18.5 percent of coarse grain consumption; the drawdown reduced the wheat stock to 17 percent and coarse grains to 14 percent. Comparable beginning-year stock figures in 1972/73 were 20 percent for wheat and 14 percent for coarse grains; they fell to 12.5 percent and 10 percent, respectively. Thus the world's margin of cereal reserves at the beginning of the 1972/73 agri-shock was not much larger than it was at the end of the 1965/66 shock, with predictable consequences for prices. Because of a succession of poor crops - in

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India in 1972/73, in the United States in 1974, and in the Soviet Union again in 1975 - there has been no recovery of stocks since the 1972 drawdown. World stocks of wheat and coarse grains at the beginning of the 1975/76 marketing year were estimated to be 15 percent and 8 percent, respectively, of the previous year's consumption.

These experiences lend support to the view that purposeful action should be taken to rebuild and to maintain grain reserves. Exporting and importing countries alike have been alarmed at high grain prices and their spreading effect on domestic food prices and on rates of overall inflation. The availability of supplies has been in question on occasion, even in rich countries, and for the poorest countries the situation could have become catastrophic. It would seem to be prudent policy, therefore, to recreate grain stocks that will be more nearly adequate to cope with future contingencies - a conclusion reached at the World Food Conference in Rome in 1974. Since the conference, the United States has made a specific proposal for an international grain reserve system. Agreement on the elements of such a system is not yet in sight, however, and the international debate probably will continue for some time to come.

As reasonable as the idea of reconstituting cereal stocks may seem, its realization will be anything but simple. In the past most stocks of grain available to meet unusual needs - that is, reserves in excess of normal inventories - have been held by only two countries, the United States and Canada. Neither country had accumulated these holdings as a precaution against poor crops at home or elsewhere. Rather, stock acquisition had been dictated by the need to hold undesired surpluses off the market in order to sustain farm prices. In effect these sizeable reserves were the unintended result of national price support policies during a period when North American crop yields were advancing at a rapid pace.

Although U. S. -Canadian stock surpluses have demonstrated that cereal prices could be held stable for a lengthy period, they have cast little light on how international reserve policy might work. No usable precedent exists for such an undertaking. The negotiators of a multilateral system will have to start from scratch to devise responses to some exceedingly difficult questions. What is the objective of a grain reserve policy to be: to ensure against famine, to stabilize cereal markets (prices) generally, or both? Which grains should be held in contingency reserves? Wheat alone, the most widely used cereal? Or coarse grains as well? And what of rice, which is the basic food for some of the largest, consuming countries but which has not usually been held in reserve except as working inventories? How large a reserve is necessary? This will depend, of course, on how much insurance is desired against which risks. When should grain be bought for stocks and when should it be sold? Should the indicator be market price, or should it depend on the physical quantities of grain produced or put in stocks?

Who should hold reserves, and where should reserves be located? What countries must participate to make a reserve scheme viable? What of the USSR and the People's Republic of China, both of whom are important elements in the grain trade? What rules would govern the release of reserves against famine? It is the better part of wisdom to recognize that at this stage definitive answers to all or even most of these questions are unlikely. If an experiment in so largely uncharted an area is to be launched, the parties to it undoubtedly must proceed to a considerable extent by trial and error. Nonetheless, some initial judgments and decisions on a few key questions will be necessary, and the following suggestions are offered.

The Supply-Demand Balance for Cereals

Supply capacity of exporting countries. This discussion rests on two general propositions: 1. For reasons explained below, any world grain reserve policy will have to be based on rebuilding stocks of wheat and coarse grains, or of wheat only. Wheat is the more versatile of the two as it can be fed to animals (at high cost), and it is the more important in world trade; but a stock arrangement for wheat alone would nonetheless have to reflect requirements for all grains and would be a doubtful policy, economically and politically. Therefore stock requirements for both categories of cereals will be considered in this analysis. 2. These stocks in practice probably will have to be built from the surpluses over domestic consumption produced in a small number of countries: for wheat, the United States, Canada, Australia, and Argentina; for coarse grains, these four countries plus South Africa and Thailand.

The focus on wheat and the coarse grains reflects a judgment that the third great cereal, rice, cannot have an important part in a systematic buildup of world reserves. In recent years rice has accounted for about one-quarter of the volume of cereals used throughout the world; in some countries it is a principal food. But few of the producing countries generate exportable surpluses; and rice has been declining sharply as a proportion of world trade in cereals (to about 5%). Furthermore, because rice is a high-value crop with a shorter storage life than other cereals, the cost of holding stocks in excess of working inventories would be substantial. Lately, only Japan has been producing surpluses resulting in significant carry-over stocks. As for the sources of surplus wheat and coarse grains, only the six countries listed have been net exporters on a significant scale long enough to be counted as reliable suppliers. The United States alone regularly accounts for half or more of the total grain exports of the net exporting group. Although other countries may join this group as time goes on, it is improbable that their contribution over the next few years could significantly alter the world supply picture.

An examination of the recent history of grain supplies and their disposition in the exporting countries will help to provide a basis for judging the prospects for rebuilding stocks in the future. Tables 1 and 2 set

forth the principal data, including the supply potentially available for export (that is, the difference between output plus carry-over stocks and domestic consumption) for the marketing years 1960 through 1974. These data show quite wide fluctuations in production. Domestic consumption of wheat has been edging up slowly over time The use of coarse grain has expanded more rapidly, though it suffered a sharp setback in 1974/75. In all, the supplies of both wheat and coarse grains available for export held relatively constant at high levels until recently. Until the export surge in 1972, cereal supplies available to meet export demand seemed to be comfortably and sometimes embarrassingly large. But the recent stock levels (see column 5) represent only a "pipeline" supply, i. e. the amounts needed for consumption between harvests.

A key point is that some of the wide variations in output were the result of decisions, usually governmental, to limit or expand the area planted to cereals (see table 3). In the case of wheat, output fell sharply

Table 1. Exporting Countries: Wheat Production, Consumption, Surpluses, and Net Exports, 1960-75[a]

(Millions of metric tons)

Marketing year	*Production*	*Consumption*	*Current crop surplus*	*Beginning stock*	*Total supply for export and carry-over*	*Net exports*
1960-61	62.7	26.3	36.4	54.9	91.3	34.9
1961-62	53.6	25.8	27.8	56.5	84.3	36.9
1962-63	59.2	25.5	33.7	47.3	81.0	34.1
1963-64	68.7	26.3	42.4	46.9	89.3	49.7
1964-65	72.5	28.3	44.2	39.8	84.0	43.8
1965-66	66.7	30.7	36.0	40.2	76.2	49.5
1966-67	76.9	29.6	47.3	26.6	73.9	44.5
1967-68	71.9	29.2	42.7	29.6	72.3	37.1
1968-69	80.6	31.3	49.3	35.2	84.5	31.4
1969-70	75.1	32.5	42.6	53.0	95.6	36.0
1970-71	58.6	32.4	26.2	59.6	85.8	41.7
1971-72	72.6	35.5	37.1	44.4	81.5	40.0
1972-73	69.9	34.0	35.9	41.4	77.4	54.3
1973-74	81.4	33.1	48.3	22.7	71.0	49.2
1974-75	79.0	31.0	48.0	19.8	67.8	49.5

Sources: For 1960-61 through 1973-74, U.S. Department of Agriculture, Foreign Agricultural Service, *Foreign Agriculture Circular*, FG 10-74 (April 1974), pp. 7, 8, 18, 101. For 1973-74 through 1974-75, ibid., FG 12-75 (October 7, 1975), pp. 4, 18, 23. Figures are rounded; some 1974-75 figures are preliminary.

a. Exporting countries are the United States, Canada, Australia, and Argentina.

Table 2. Exporting Countries: Coarse Grain Production, Consumption, Surpluses, and Net Exports, 1960-74

(Millions of metric tons)

Marketing year	*Production*	*Consumption*	*Current crop surplus*	*Beginning stock*	*Total supply for export and carryover*	*Net exports*
1960-61	171.0	143.4	27.6	74.3	101.9	17.8
1961-62	153.1	143.7	9.4	84.1	93.5	23.4
1962-63	158.0	140.6	17.4	70.3	87.7	22.9
1963-64	170.6	139.7	30.9	64.9	95.8	25.4
1964-65	150.5	139.4	11.1	70.4	81.5	26.1
1965-66	176.5	152.9	23.6	55.4	79.0	34.4
1966-67	185.8	156.5	29.3	44.6	73.9	31.0
1967-68	194.4	156.7	37.7	42.9	80.6	30.6
1968-69	192.2	163.7	28.5	50.5	79.0	24.7
1969-70	204.3	174.0	30.3	55.3	85.6	31.1
1970-71	196.1	171.1	25.0	54.3	79.3	39.1
1971-72	239.7	184.1	55.6	40.4	96.0	40.5
1972-73	225.8	191.1	34.7	55.4	90.1	53.2
1973-74	241.3	190.9	50.4	37.0	87.4	56.5
1974-75	196.5	155.0	41.5	29.3	70.8	54.5

Sources: For 1960-61 through 1973-74, U.S. Department of Agriculture, Foreign Agricultural Service, *Foreign Agriculture Circular*, FG 10-74 (April 1974), pp. 7, 8, 18, 85, 95, 101. For 1974-75, ibid., FG 12-75 (Oct. 7, 1975), p. 5. Figures for 1974-75 are preliminary.

a. Exporting countries are United States, Canada, Australia, Argentina, Thailand, and South Africa.

in 1961 because of low yields in the United States and especially in Canada. But the prolonged production slump after 1968 through 1972 was largely due to idled acreage; in fact, wheat acreage did not again reach the 1968 level until the 1974 crop year. The production of coarse grains fell markedly from previous-year levels in 1961, 1964, 1970, and 1974. Except for 1970, when a corn blight reduced yields in the United States, and the U.S. drought year 1974, reduced plantings were the principal cause of the declines. The drop in the consumption of coarse grains in the exporting countries in 1974/75 undoubtedly was a response to high prices.

In order to project output from 1976 through 1980, cereal acreage in the exporting countries is assumed to be more or less fully used. "Full production" is defined as follows: 1. For wheat, a harvested area of 28 million hectares (the projected figure for 1975/76) is taken to be the average full use figure in the United States over the next few years. The 1974/75 figure for the other exporting countries is well below historic highs; thus the average for 1966-68, or 27 million hectares, is used in this analysis. 2. In the case of coarse grains, the American harvested area for the 1975 crop year was about 42 million hectares. While this is below peak levels achieved in the past,

Table 3. Exporting Countries: Harvested Area and Yields, 1960-75

(Area in thousands of hectares; yields in metric tons per hectare)

Crop year	Wheat				Coarse Grains			
	United States		Other exporters[a]		United States		Other exporters[a]	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield
1960-61	20,995	1.76	18,992	1.36	52,269	2.71	20,414	1.42
1961-62	20,871	1.61	20,624	0.96	43,249	2.95	19,009	1.35
1962-63	17,681	1.68	21,263	1.38	42,036	3.08	18,897	1.50
1963-64	18,416	1.69	23,501	1.60	43,186	3.25	20,712	1.46
1964-65	20,139	1.73	25,405	1.48	40,001	3.06	19,858	1.40
1965-66	20,057	1.79	23,142	1.33	39,491	3.65	20,238	1.60
1966-67	20,088	1.77	25,657	1.62	40,153	3.61	22,129	1.85
1967-68	23,627	1.74	27,084	1.14	41,287	3.95	22,740	1.39
1968-69	22,174	1.91	28,590	1.34	39,791	3.90	23,597	1.56
1969-70	19,089	2.06	24,781	1.45	39,187	4.13	24,791	1.72
1970-71	17,630	2.09	15,232	1.44	40,761	3.59	25,260	1.98
1971-72	19,294	2.28	19,307	1.48	43,718	4.34	25,763	1.94
1972-73	19,136	2.20	21,383	1.31	38,489	4.73	28,492	1.79
1973-74	21,803	2.14	22,826	1.53	41,835	4.46	27,260	2.00
1974-75	26,500	1.84	21,153	1.43	40,800	3.68	25,400	1.96

Sources: For 1960-61 through 1973-74, U.S. Department of Agriculture, Foreign Agricultural Service, *Foreign Agriculture Circular*, FG 10-74 (April 1974), pp. 7, 8, 18, 85, 95, 101. For 1974-75, ibid., FG 12-75 (October 7, 1975), pp. 18, 19, 23, except other exporters' coarse grains, which are estimates.

a. Weighted averages. Other exporters include Canada, Australia, Argentina, South Africa, and Thailand.

it reflects planting decisions based on high prices and made in the absence of acreage restrictions and is therefore taken as a short-run maximum. For other exporting countries, the average of 27 million hectares for the 1972/74 period is assumed to be the maximum planted area for the near future.

Average yields in the exporting countries have been erratic but rising, and the United States, the largest producer, has had the largest percentage gains. Projecting yields from trends in the data for the years 1960-74 gives the results for 1976 and thereafter shown in Table 4.

The limitations of these mechanical projections are evident enough. The assumptions underlying them are, first, that available acreage will be substantially unrestricted and, second, that yields will grow according to trend. These assumptions, in turn, rest on the suppositions that prices will be high enough to ensure both a large planted area and the use of enough fertilizer and other inputs to keep yields rising, and that weather and other elements bearing on yields will be favorable. Under such conditions, the tables suggest that the exporting countries could be producing cereal surpluses in the near future at levels substantially higher than in the past - for example almost half again as large as the 1971-74 average. The adequacy of such surpluses

Table 4. Exporting Countries: Trends in Supply, Domestic Consumption, and Exportable Surpluses, Wheat and Coarse Grains, 1976-80, and Actual Averages for 1971-74

	Area (millions of hectares)		*Trend yield (metric tons per hectare)*		*Output (millions of metric tons)*	*Domestic use[a] (millions of metric tons)*	*Export surplus (millions of metric tons)*
	United States	*Other exporters*	*United States*	*Other exporters*			
				Wheat			
1971–74 average	21.7	21.2	2.12	1.44	76.5	33.3	43.2
1976	28.0[b]	27.0[b]	2.24	1.49	103.0	36.2	66.8
1977	28.0	27.0	2.28	1.50	104.3	36.9	67.4
1978	28.0	27.0	2.33	1.51	106.0	37.7	68.3
1979	28.0	27.0	2.37	1.53	107.7	38.5	69.2
1980	28.0	27.0	2.42	1.54	109.3	39.3	70.0
				Coarse Grains			
1971–74 average	41.2	26.7	4.30	1.92	225.8	180.3	45.5
1976	42.0[b]	27.0[b]	4.80	2.10	258.3	191.9	66.4
1977	42.0	27.0	4.95	2.16	266.2	195.9	70.3
1978	42.0	27.0	5.11	2.22	274.6	200.0	74.6
1979	42.0	27.0	5.27	2.28	282.9	204.2	78.7
1980	42.0	27.0	5.44	2.35	291.9	208.5	83.4

Source: Derived from tables 2-1, 2-2, and 2-3.
a. Based on exponential time trend.
b. Assumed full production area.

for meeting export needs and for rebuilding stocks will depend, however, on what happens to cereal requirements in the importing countries.

Shortfalls in Importing Countries. Here the procedure is to calculate consumption and local production trends for wheat and coarse grains in the importing countries on the basis of 1960/61 to 1974/75 data and to project these trends to 1980. The difference between the trend figures for projected consumption and domestic production will be the shortfalls that will have to be covered by imports (or reserves) if consumption is indeed to remain on trend. Table 5 shows projected average shortfalls growing from 50 million to 54 million metric tons for wheat, and from 58 million to 74 million metric tons for coarse grains, between 1976 and 1980.

These projections reflect past increases in grain consumption resulting from the growth of population and income, but also are based on the stable low grain prices during most of the period considered. On the production side, they represent a continuation of the trends in yields and planted areas that have characterized the past fifteen years. In respect to both consumption and production the prospective shortfalls may be overstated. That is, the growth of consumption may be slowed by higher prices, and acreage and yields may grow faster than the trends indicate. But in many importing regions the likelihood of popular resistance to cuts in consumption may require

Table 5. Importing Countries: Projected Shortfall between Consumption Requirements and Domestic Production, 1976-80

(Millions of metric tons)

Year	Wheat			Coarse grains		
	Trend consumption	Trend production	Average shortfall	Trend consumption	Trend production	Average shortfall
1976	364.9	315.0	49.9	450.2	391.9	58.3
1977	378.0	327.1	50.9	466.2	404.2	62.0
1978	391.6	339.6	52.0	482.7	416.8	65.9
1979	405.7	352.7	53.0	499.8	429.9	69.9
1980	420.3	366.2	54.1	517.5	443.3	74.2

subsidizing food supplies; and a production response significantly above trend seems improbable in the short run, given the economic and institutional obstacles to be overcome. Within their limits, in any case, the trends point to increasing requirements for imports of both wheat and the coarse grains. The necessary supplies to cover these requirements will have to be provided largely by those countries that have consistently been net exporters.

The margin for rebuilding stocks. When the trends in export surpluses shown in Table 4 are compared with the trends in importing country shortfalls in Table 5, a pattern of persistent but limited potential surpluses for reserves emerges (Table 6). But the margins are surprisingly narrow, in view of the assumption of full output in the exporting countries. The figures in Table 6, of course, should not be taken as literal prophecies about the state of grain markets over the next few years. Weather, governmental decisions, and price changes will affect year-to-year events and cause the figures to vary widely from those resulting from a projection of past trends. Certain circumstances would be favorable to stock building. One would be a

Table 6. Projected Wheat and Coarse Grain Supply-Demand Trends, 1976-80

(Millions of metric tons)

Year	Wheat			Coarse grains		
	Exporters' surplus[a]	Importers' shortfall[b]	Potential surplus for building reserves	Exporters' surplus[a]	Importers' shortfall[b]	Potential surplus for building reserves
1976	66.8	49.9	16.9	66.4	58.3	8.1
1977	67.4	50.9	16.5	70.3	62.0	8.3
1978	68.3	52.0	16.3	74.6	65.9	8.7
1979	69.2	53.0	16.2	78.7	69.9	8.8
1980	70.0	54.1	15.9	83.4	74.2	9.2

year of above average harvests in the USSR and India, along with fine weather and perhaps acreage responses in the big exporting countries better than those assumed. Another would be a period of below-trend consumption of coarse grains in North America, Western Europe, and Japan as a consequence of high prices. These developments could bring large early surpluses of wheat or coarse grains, or both, far beyond the comparatively narrow margins shown in Table 6. On the other hand, a succession or a coincidence of mediocre harvests, particularly in the Soviet Union or North America, would reduce the possibility of accumulating a cereal reserve.

In any event, the data suggest that the tight demand-supply situation that has prevailed since 1972 will not automatically be replaced by large surpluses out of which reserve stocks can be quickly replenished, even at full production in the exporting countries. Since the carry-over of grains at the beginning of the 1975/76 marketing year apparently was near minimum pipeline stock levels, restocking even to the average levels of 1969-72 (when exporters' beginning stocks, including pipeline inventories, averaged about 50 million tons for each of the cereal categories) could require several good years.

Reserve Stock Targets: Stabilization Objective

A decision to proceed with a policy of reconstituting grain reserves should be made when there is a relatively easy market situation. The effect that an attempt to accumulate stocks in a time of stringent supplies would have on cereal prices would be unacceptable politically, and would make no sense as a stabilization objective. Nonetheless, tentative reserve targets would have to be established in advance and based on a calculation of possible requirements for the use of stocks.

Reserve stocks are needed for insurance against either or both of two kinds of contingencies: periodic bad harvests in the importing countries, or low export surpluses resulting from below-trend crop yields in the exporting countries. In other words, reserves may be needed to meet either unusual import demands or a serious shortfall in the supplies available for export. To ensure against all possible combinations of adverse fluctuations, however, would be infeasible. In practice the aim might be to set targets for reserves that would cover the major foreseeable risks at a high level of probability, on the assumption that the various possible downward deviations from output trends would not coincide.

In the case of wheat, fluctuations below trend in the importing countries will present the major risk. The wheat output of importing countries is almost four times that of exporting countries. Variations downward from trend output in the importing countries therefore give

proportionately large shortfalls as far as the world market is concerned. Similar variations in the output of exporting countries give much smaller volume changes; and the size of the variations, at least in the data for the United States, promises to be smaller than in importing countries. Thus it would appear to be sound policy to focus on possible shortfalls in importing countries as the principal index to reserve stock requirements for wheat. For the coarse grains, on the other hand, fluctuations in production in the United States will be the main hazard to insure against. The United States alone produces 25-30 percent of world output and is by far the dominant exporter. Recent fluctuations in yields show that downward variations in output in the United States can be quite wide. So reserve policy could prudently be built around possible U. S. output fluctuations, assuming that U. S. acreage would be kept at full production levels, as defined, and that bad weather and crop diseases are the risks to be insured against.

For this analysis a range of possible cereal shortfalls has been calculated from trends in both importing and exporting countries and stated as probabilities, or "confidence intervals." At the 95 percent confidence interval, the probability is one in twenty that variations from trend will be as large or larger than the calculated figure. In order to cover a specific risk up to 95 percent probability, the reserve target would have to be set at the corresponding level shown in the calculations. Lower or higher insurance objectives would require smaller or larger reserves.

On these bases, potential reserve requirements can be estimated for wheat and for coarse grains over the period 1976-80. For this purpose shortfall calculations at the 95 percent confidence interval are used for the prime risks. Table 7 gives the relevant figures,

Table 7. Estimated Reserve Requirements, Wheat and Coarse Grains, 1976-80

(Millions of metric tons)

	Wheat			*Coarse grains*		
Year	*Importing countries' shortfall* (1)	*Exporters' surplus* (2)	*Reserve requirements* (3)	*Importing countries' shortfall* (1)	*Exporters' surplus* (2)	*Reserve requirement* (3)
1976	88.8	66.8	22.0	58.3	29.9	28.4
1977	91.6	67.4	24.2	62.0	32.1	29.9
1978	94.4	68.3	26.1	65.9	35.0	30.9
1979	97.4	69.2	28.2	69.9	37.6	32.3
1980	100.5	70.0	30.5	74.2	40.6	33.6

which indicate a rising level of reserve requirements, both for wheat and for coarse grains. Potential wheat shortfalls in the importing countries grow faster than trend surpluses available for exports. Similarly, the trend of importing country shortfalls in coarse grains rises quite steeply, while the assumption of a below-trend American harvest fixes hypothetical exporter surpluses at low levels. This procedure results in requirements for wheat reserves rising from 22 million tons in 1976 to 31 million tons in 1980, and coarse grain reserves growing from 28 million tons to 34 million tons over the same period.

These amounts are based on the contingencies of poor crops of wheat and coarse grains. A shortfall in rice production would further increase the requirement for wheat and coarse grain reserves, since it is assumed that rice stocks will not ordinarily exceed working inventories and that drawings will have to be made on wheat and coarse grain supplies to make up rice deficits. A trend series for 1975 through 1980 has been obtained by fitting an annual series for world rice production, 1960-74, to an exponential function of time. Following procedures described earlier, deviations from trend have been calculated at the 95 percent confidence interval. On this basis the possible rice shortfalls to be taken into account are 14 million tons in 1976 and 16 million tons in 1980.

In order to ensure against all three contingencies - a wheat shortfall in the importing countries, a poor coarse grain harvest in the United States, plus a serious failure of the world rice crop - the total grain reserve requirement (wheat and coarse grains combined) might come to 64 million tons in 1976, rising to 80 million tons in 1980. Similar amounts have been estimated for reserve requirements by FAO and by the U. S. Department of Agriculture, using somewhat different methodologies. But whether prudence would require reserves of that magnitude is not a definitively answerable question. On the one hand, the possible downward fluctuations selected for this study can be expected to be independent of one another to a large extent and are unlikely to come together in the same year. Moreover, since the grains are substitutable - within limits - and if it is assumed that coarse grains are used with a considerable degree of flexibility in the exporting countries, smaller insurance stocks might be justified. On the other hand, the combination of adverse circumstances selected for discussion here is only one of a large universe of possible combinations. A poor wheat harvest in the USSR alone would probably mean an importing-country shortfall close to the magnitude considered here. It would normally be accompanied by a poor Soviet coarse grain harvest as well, leading to a very large potential claim on world cereal supplies. And, of course, poor harvests of any of the grains could occur in major consuming or producing countries in successive years, or at short intervals, so that a small original reserve stock would be drawn down and could not be replenished.

It is unnecessary to belabor the qualifications that must be placed on

any calculation of reserve requirements. They are inevitably based on data for a fairly short and not always representative period and on assumptions that could be far off the mark. At best they are indicative, not predictive. But what they do suggest is that the reserves needed to ensure against the chief risks of low cereal crops must be quite large, and must increase over time - that is, if consumption and production trends derived from past experience provide any basis for forecasts. Indeed it may be that the stocks that seemed so large and burdensome during the 1960s would now be less than adequate for insurance against poor harvests.

These reserve projections deal with world requirements. If stocks of these magnitudes were to be created and were to be releasable in the circumstances assumed, they could serve both as a stabilizing element in commercial markets and as insurance against the threat of famine in the developing countries. By hypothesis they would be adequate to cover world export supply deficits or import demand increases of the kind identified as the major risks. With these reserves available, commercial buyers would be more adequately assured of normal supplies and protected against extraordinary price rises, while the poorest developing countries would be able to avoid extreme cuts in consumption in the face of bad harvests.

It is uncertain, however, that reserves sufficient for such a hypothetical global deficit will or could be recreated in the short run. If reserves are to be much less than that, the first requirement of a reserve policy presumably would be to establish contingency stocks against the possibility of a catastrophic human situation in certain of the developing countries. Reserves might be earmarked for release primarily, or only, in the event of threatened famine.

Famine Reserve Issues

Much of the current discussion of food or grain reserves has hinged on concern over the plight of countries where average diets are glaringly inadequate and where agricultural production has kept barely ahead of population growth. Reserve stock policy, of course, could bring no direct improvement either to national levels of nutrition or to farm output in these countries. But a famine reserve could guarantee, at least within predetermined limits, that in emergencies no country would be precluded from meeting its minimum food needs because of its inability to finance the requisite imports.

The Intergovernmental Committee of the World Food Program (WFP) has defined food emergencies as follows: "International food emergencies are ... urgent situations in which there is clear evidence that an event has occurred which causes human suffering or loss of livestock and which the government concerned has not the means to remedy,

and it is a demonstrably abnormal event which produces dislocation in the life of the community on an exceptional scale." If this definition were taken as the basis for action, a famine reserve would be applicable to the lowest-income countries, where natural or man-made disasters could create food shortages beyond the capacities of governments to deal with them. Countries that have chronically or periodically had heavy food deficits are particularly vulnerable. Most countries with less than $150-$200 per capita gross national product (GNP) are small, and their potential cereal requirements are modest; several, like Burma, are net food exporters. The critical exceptions are the countries of South Asia - India, Pakistan, Bangladesh, and Sri Lanka. These countries together have 780 million people whose consumption of cereals in recent years has been in the range of 114 million to 126 million tons, more than 10 percent of the world total. Since crop failures elsewhere among the poorest countries would not necessarily coincide with those in South Asia, a reserve adequate for a major South Asian contingency would be sufficient to meet other potential famine situations, which in any case would be far less severe. For an estimate of possible reserve requirements, therefore, trends in South Asian shortfalls are used here as a proxy for the low-income countries taken together.

Famine reserve quantities. Actual yearly shortfalls in South Asia during 1960-73 were mostly in the range of 4.5 million to 7 million tons, but with a bulge in 1964-67, when the average was 12 million and the high 14 million. Trend consumption during this fourteen-year period was rising annually at a rate of 2.8 percent, trend production at 3.1 percent. When these trends are extrapolated, the results for 1976 through 1980 indicate annual shortfalls decline slowly from 7.3 to 6.8 million tons. But the prospect changes markedly when a bad harvest is introduced into the projection. If the low output of all cereals that is probable once in twenty years is assumed, the possible shortfalls, 1976-80, would be in the range of 24-27 million tons. Since, however, the countries at risk normally are importers, it would be overcounting to place the need for reserves at this level. Cereal imports from 1969 through 1974 averaged about 5 percent of total consumption: if this rate is applied to consumption trends, annual imports for 1976-80 would be on the order of 6 million to 7 million tons. Subtracting these amounts from the projected shortfalls give 18-20 million tons (all grains) as a possible contingency reserve target. At that level, in most probable short-run circumstances any single-year emergency requirements in South Asia - and other famine-liable areas - would be covered.

Thus the grain requirements for insurance against near-term famine threats appear to be about one-third of the grain reserve needed over the period 1976-80 for all insurance purposes. This amount is not inconsiderable, but the problems of organizing and managing a famine reserve may be more complicated than deciding on how much.

Burden-sharing and management issues. If the world community were to agree on the establishment of grain reserves to cope with global fluctuations in requirements and supplies, it might be feasible as well as reasonable to agree further that the developed country participants would earmark reserves in one way or another for allocation to famine-threatened regions. A precedent of a sort exists in the WFP, where the contributions to international food aid are spread among twenty countries; in those cases where commodities are pledged to the program, they are held in donor countries until called for by the program staff. Burden-sharing under the WFP is inequitable and out of date - the USSR does not take part, Japan's share is only 1.4 percent, and the contributions of the oil-producing countries are not commensurate with their new affluence. But the underlying concept could be relevant to a famine reserve arrangement underwritten by the high-income countries on a basis proportionate to their respective GNPs or on the basis of their shares in a broader grain reserve.

Like any stockpile arrangement, a famine reserve would involve storage and interest costs; and since this reserve presumably would be distributed on a grant basis, the initial investment could not be recaptured through eventual sales. Suppose a famine reserve of 20 million tons were made up wholly of wheat, the most usable and transportable cereal. If its cost proved to be $110 per ton at a U.S. port, the initial outlay would be $2 billion, to be shared, putatively, among the rich countries in the world. Carrying costs would depend on the prevailing interest rate and the expenses of storage. Assuming a real interest rate of 3 percent (e.g. 8 percent interest and 5 percent inflation), and storage charges including quality maintenance of $7.50 per ton, annual costs would be about $210 million in constant dollars. An offsetting consideration is that it must be assumed that in the absence of a reserve stock, the high-income countries would in any case be impelled to respond to an impending famine by buying grain for relief shipments.

The most sensitive issues in providing a famine emergency stock probably would relate to its management as a genuine reserve. At one extreme is the possibility that it would be treated as a new variety of food aid to be released to offset the low levels of nutrition prevailing in the poorest countries; that is, that it would be released too fast and too easily. At the other extreme might be a reluctance on the part of some donor countries to agree to release stocks in their possession, even in an apparently clear and present famine threat - as for instance if cereal prices were rising fast and if domestic political pressures called for action to check their rise.

Famine contingency stocks could of course be placed physically in the countries that are most liable to require help. The responsibilities for management could be left to the governments of these

countries; each could decide when reserves should be put into its rationing system or on the market. This would assure that stocks would infallibly be under the control of national governments in emergencies, and transportation delays or other bottlenecks could be minimized by locating supplies in the potential shortage areas in advance of emergencies. But as a practical matter, locating emergency stocks in countries deemed likely to need them would effectively remove them from an international system. These nations could not be expected to feel bound to observe international guidelines for the release of stocks to another country where claims for help might be judged (by outside observers) to be more urgent. Nonetheless, the idea that stocks, even if internationally financed, must be nationally held and controlled may be the most widely, or the only, acceptable one; it has the imprimatur of the Food and Agriculture Organization, and its adoption would simplify the problem of reserve stock management if decisionmaking would be left in the main to the governments in the countries concerned. While reserves might be used imprudently, there would be the implicit sanction that replenishment after a clearly unnecessary release would be difficult to accomplish.

A middle course would be to maintain some stocks in potential famine areas along with designated famine reserve stocks in donor countries. Local emergency stocks in low-income areas might be financed partly or totally by high-income countries on an internationally agreed upon basis, possibly as an adjunct to food aid. Donor countries then would earmark additional stocks from their own reserves to be used for famine relief, subject to the call of an international body established to decide about emergency famine assistance needs. Guidelines for the release of these latter stocks would be strict, for their use as additions to regular food aid would threaten to discredit the concept of insurance against genuine threats of famine. Decisions presumably would be based on consultations with such international agencies as the World Bank, the International Monetary Fund, or the WFP's Intergovernmental Committee.

Reasons for Establishing an International Reserve: Summary

A multilateral agreement to establish reserves of cereals would amount to a substantial new experiment in international cooperation. Not surprisingly, the problems of negotiating such an undertaking appear to be formidable. The principal requisites of an agreement are clear enough, however, and should not present insuperable obstacles if the main negotiating parties are prepared to consider the issues seriously. And the arguments for going forward, on examination, are quite compelling.

First, in the affluent industrial countries sharp upward changes in cereal prices often have a pervasive influence on all food prices and the overall price level. The complications for national economic

policy, or for demand management, that follow from these inflationary developments can keep economic growth below its potential, at large economic and social costs. A reserve stock policy that could keep cereal price changes within a less disruptive range could thus make an impressive contribution to the welfare of the industrial nations and, because of the dominant role of these nations in the world economy, of the developing countries as well.

Second, for the nonindustrial countries, and especially the poorest among them, higher prices for cereals can work a variety of hardships: (1) directly on development programs and prospects, by forcing reductions in the volume of nonfood imports; (2) on economic stability by way of heightened inflationary pressures; and (3) on levels of food consumption through cutbacks in cereal imports - in effect, a spreading and worsening of preexisting malnutrition among the poorest members of these societies. These effects should also include adverse political consequences of price changes, which could appear in both rich and poor countries.

Third, in certain of the low-income countries, notably in South Asia, there is an inherent threat of widespread famine in any failure of a major domestic cereal crop. While in principle the amount of grain that might be needed to cope with any likely famine emergency could be mobilized by reductions in consumption elsewhere in the world, a prompt, adequate response would be difficult to organize unless reserve stocks were available to be drawn upon.

Inferior alternatives to world reserves. The possible alternatives to financing and managing grain reserves multilaterally, while better than no action at all, appear to be subject to liabilities or inadequacies. The most obvious is a return to the past by building up North American reserves. It is possible that the United States, or the United States and Canada, will once again find it politically necessary to accumulate stocks to cope with surplus domestic production. To rely on this possibility, however, would involve the risk that in North America future policy, like that in the late 1960s, would be to cut the acreage planted to cereals rather than to let surpluses accumulate. Given the critical role of the North American cereal output in the world grain economy, such decisions could greatly increase the world's vulnerability to a bad harvest in a major producing or consuming country or region. Or if the United States and Canada rebuilt stocks on their own, they might find it politically requisite to use them primarily to defend domestic markets against fluctuations and to use export restrictions to put the main price and cost burdens of short supply situations on importing countries.

The Food and Agriculture Organization (FAO) offers another alternative, which in effect constitutes a reserve proposal with guidelines but without commitments. The FAO has proposed a series of individually

determined and loosely coordinated national stocks. This would set aside the principle of risk pooling, apparently out of concern for national sovereignty. It would put a premium on most countries waiting to see what a few big importing and exporting countries would do. And the absence of commitments to common guidelines for the acquisition and disposal of stocks would make questionable their usefulness in times of market stringency or surplus.

And finally, bilateral supply and purchase arrangements between a few large exporters and importers, without provision for stocks, at most would shift burdens to others in periods of short supplies, with potentially disruptive effects on established trade patterns and perhaps on international comity. The U. S. -Soviet agreement of October, 1975, for example, has yet to be tested by either bumper crops or bad harvests; but restriction of grain flows between the two countries to a range of 6-8 million tons a year does not in itself prevent destabilizing Soviet purchases (or resale) of grain in other markets. If such arrangements were buttressed by agreements among the parties to hold stocks, they would raise most of the same problems of joint management as those of a multilateral reserve scheme, but in a more divisive way.

Suggestions for Setting Up a Grain Reserve

The essential elements of an international grain reserve arrangement might be as follows:

1. Size and composition. The calculations of trends in exporting and importing countries suggest that single-year risks of substantial grain shortfalls might be covered by initial contingency reserves on the order of 60 million tons, divided between wheat and coarse grains in roughly equal fashion, with the amounts rising by 1980 to about 75-80 million tons. Rice would have a small role, if any, in reserves, because of both its high costs and its limited storage life. But possible shortfalls in rice production could be covered by holding stocks of other cereals.

2. Participation. Contributors to the financing of reserves should include in principle all the industrial countries, East and West, as well as Argentina and South Africa. If the Soviet Union and Eastern Europe were to opt out, stock requirements could be considerably reduced, but only if advance arrangements were made for coordinated export controls and discriminatory pricing to assure that a crop failure in the USSR (or in any other nonparticipating nation) would not unduly disrupt the grain markets of other countries.

3. Cost sharing. The costs of a grain reserve would be interest and storage charges, plus the acquisition expenditures for any stocks eventually used for famine relief grants. Acquisition outlays otherwise could

be regarded as an investment. A 60-million-ton reserve costing upwards of $6 billion to acquire might involve annual carrying charges of about $640 million in constant 1975 dollars. Profits from sales could cover some, all, or more than these costs, depending on the time period between accumulation and the disposal of the stocks and on the margin between acquisition and selling prices.

A principal criterion for deciding on fair shares of the costs of maintaining international reserves would be the level of a country's grain consumption, since much of the benefits of stable markets could be expected to accrue to consumers. Other criteria would relate to the volume of exports and/or imports, as reserves might be held in either the exporting or importing countries, or in both, with storage costs normally covered by the holding country. The U.S. proposal envisages that cost sharing would be based on some combination of trade volume, GNP levels, and the extent of variability in production. It is clear that the criteria to be used in allocating costs, the weights to be given to each, and the resulting balance between producers and consumers, and industrial vs. developing countries, are certain to be the subject of considerable dispute since there are a number of different ways in which benefits could be measured.

4. Reserve stock management. Stocks would be "national" in the sense that individual shares would be nationally owned and, according to choice, nationally located. Participants would be committed to acquire stocks according to agreed upon guidelines, and the most generally suitable would be prices in world markets. Disposals also would be determined by market price developments. Illustratively, purchases would be presumptive at 10 percent above the floor price and mandatory at the ceiling. The wider the price range, of course, the smaller the reserve requirements would be; a fairly wide range within which market forces could operate would be necessary in any case during a stock build-up period. A price range in which the maximum price were set at 40 percent above the minimum price might be a good starting point, on both political and economic grounds.

5. Famine reserve. The level of cereal reserves needed to give substantial insurance of being able to meet a major famine emergency in the poorest countries may be on the order of 20 million tons. This amount would be an integral part of a larger market stabilization reserve, with some form of earmarking to assure its availability in a famine situation. It would be financed largely or entirely by the high-income participants, and its use would depend on an internationally approved set of criteria.

6. International reserves and national farm policies. The parties to an international reserve scheme could follow different domestic farm policies, as on price or income supports, without affecting thei obligations under the scheme. If, however, reserve stock goals w

achieved and surpluses continued to mount, it would be necessary to share production cutbacks among the countries involved or to raise the stock targets, or both. A reserve agreement might include provisions for gradually reducing price supports as protection if surpluses became chronic, thus leading eventually to a more rational use of agricultural resources in the industrial countries.

The North American role. The beginning of a build-up of grain reserves will depend on harvests good enough to put significant downward pressures on world prices. This could occur, to take one likely set of circumstances, as soon as the United States and the USSR simultaneously have bumper harvests. But there should be an understanding about a reserve policy in advance of the appearance of surpluses because of the critical role of U. S. or North American cereal production in the world grain economy. For the present, and probably for some time to come, North American crops must provide the largest part of the grain needed to cover deficits elsewhere. It is of crucial importance, therefore, that market conditions should continue to induce full use of the relevant acreage in the United States and Canada.

If initial surpluses were to prompt North American acreage reductions, voluntary or officially sponsored, rather than the accumulation of adequate reserve stocks, the world's economic vulnerability to bad harvests would be greatly heightened. In particular, a low American crop in any year could mean that the margin would be lacking to cover cereal deficits in importing countries; if this situation were coupled with poor crops elsewhere, export limitation would become inevitable. The way back to any reasonable stability in world grain markets cannot be assured unless full output in North America is underwritten either by multilateral commitments or by the willingness of the United States and Canada to accept this responsibility on a unilateral basis.

[Extracted from Chapters 1, 2, 3 and 6 of Rebuilding Grain Reserves: Toward an International System.
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BUSINESS MANAGEMENT TRAINING

SCENE FROM A TRAINING INSTITUTE IN THE CARIBBEAN (PHOTO: USIS)

Entrepreneurship Development

V. G. Patel

[Entrepreneurship plays an important role in the speed and direction of economic development. A highly effective, low cost program to develop new entrepreneurs and assist them to start their own businesses has been undertaken in Ahmedabad, India.]

An entrepreneur has been described variously by different scholars. For the non-specialized environment of developing countries, an entrepreneur can be identified as one who organizes a business where none existed before, or the one who both owns and operates a business (whether it is new or not). The search is now for those individuals who possess certain essential traits of drive, ambition, energy and motivation to give a business the strong thrust it must have to succeed. They may innovate, adapt, or imitate, but they are on the look-out for better economic opportunities, are highly motivated, willing to take calculated risks and are capable of meeting the uncertainties, pressures and problems of independent ventures.

Entrepreneurs play a key role in determining the levels and rates of economic development among a complex of inter-related factors. Not only do entrepreneurs exploit the profit opportunities generated by the economy, but their action may create such opportunities for others and thereby move the economy. Rapid economic progress in developing countries calls for the willingness to engineer change and to depart from customary or traditional methods and practices in high degree. In the early stages of economic development, leadership is required for introducing technological innovations, and to break the hold of deep-rooted, traditional methods responsible for low levels of production

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and income. Countries differ in their economic endowments, socio-cultural history, and stages of economic growth, but there always are economic opportunities to be seized.

Developing Entrepreneurship

That such entrepreneurs are not just born but can be developed was the belief with which the Industrial Development Corporations of the State Government of Gujarat in India initiated an Entrepreneurship Development Program in April 1970. Under this program for developing manufacturing entrepreneurs, 293 have been trained (as of 1973) out of which 109 have already started their own industrial ventures, while 36 are ready to do so within the next 3 to 6 months. This experience could be of wider interest for the following reasons: (1) Since entrepreneurs play a crucial role in economic development, the success in expanding a supply of such entrepreneurs through deliberate measures offers an important tool for rapid expansion of investment, employment, income and production. In Gujarat, it has been treated as a "technology" for social transformation. (2) The results have been accomplished at a nominal cost. For each new entrepreneur developed, the cost comes to Rs. 300 and for each new industrial venture actually set up, the cost works out to Rs. 500. (Rs 7.50 = $1.00) In developing entrepreneurs from the educated unemployed, the cost has been Rs. 1500 per trainee and Rs. 2500 per industrial unit. The benefit/cost ratio has been quite favorable. (3) With suitable modifications for local environments, the program offers scope for adaptation in other States or countries desiring to develop new entrepreneurs, and a wider application in agriculture, commerce and services.

The entrepreneurship program was undertaken to develop a class of young, new entrepreneurs to set up their own manufacturing ventures in the State. The State has built up the necessary industrial infrastructure over the years. Investment resources are available through liberal loans and credit schemes. While entrepreneurs are coming forward in large numbers, the rate of industrial growth can be accelerated if their supply is increased. If through training a large number of potential entrepreneurs can be identified and developed, a series of new industrial ventures can be set up with direct contributions in production, income and employment. Their products will not necessarily be innovations. But the process of starting a large number of units in a variety of industries is bound to generate technological changes as existing product-uses and markets are saturated, and intensive competition forces established entrepreneurs to look for better technology for better returns.

The goal of the entrepreneurship development program is to develop owners, as contrasted to employees in large factories and establishments. Each owner-entrepreneur could generate direct employment for some 20 workers in his small scale venture. During the last 10 years, some

20,000 small industrial firms have been set up in the State generating direct employment of 400,000 workers. The average investment per employment created has been only Rs. 16,000. If 1000 new entrepreneurs are developed annually through the Entrepreneurship Program and if at least 60% of them actually set up small firms, 12,000 new jobs can be created each year directly and others due to forward and backward linkage effects. If most of the trainees and their new employees come from employees, workers and salesmen with some work experience, then their leaving present employment will create replacement employment for others in a continuous process.

In a traditionalist society where traditional roles and functions remain rigid and social institutional changes are severely restricted, certain groups dominate in their roles as employers and monopolize better economic opportunities, while others continue to be employees or unemployed. Economic development loses its meaning for most. An entrepreneurship development program with no barriers of age, education, caste, religion, previous occupation and social status can open up doors of ownership and better economic opportunities for all those possessing certain human qualities, and can develop and involve them in new economic roles.

The Search for Potential Entrepreneurs

But who are these potential entrepreneurs, and where must we look for them? A survey of industrial firms in Gujarat state in 1971 showed that traders have provided the largest source of entrepreneurs (32%) in the past, followed by employees and workers in factories (27%). From sales to manufacturing has been a natural transition for merchants, as they are better placed to observe profitable product opportunities and better equipped with business know-how and their own capital for setting up a company. On the other hand, this traditional pattern is being challenged by techno-entrepreneurs from the employee group who desire to profitably utilize their technical skill or manufacturing know-how based on work experience. 53% of the entrepreneurs had five years or more of experience in the same line, while an additional 20% had two to four years of experience either as traders or employees.

The reasoning behind the Gujarat Program was that many in the field of sales and trading and from the large group of employees and workers could be developed into owner-entrepreneurs if their motivation is strengthened, and if decision and risk-taking capacities and self-confidence are adequately developed. Further, among the large and growing number of young engineers and other educated unemployed, many might possess technical know-how or business aptitude and latent entrepreneurial traits which could be developed for them to be self-employed in small-scale manufacturing ventures.

Since not everyone can be developed into an entrepreneur, a rigorous selection process has developed over the years to ensure that only those

are taken up who have potential for entrepreneurial development. The crux of identification lies in evaluating the inner behavioral, psychological traits relevant for entrepreneurship. Accordingly, elaborate, comprehensive behavioral tests are applied to all those responding to the public announcement of the Entrepreneurship Program. The tests explore the potential in the individual for the following qualities identified by research as entrepreneurial behavior: (1) Presence of an achievement imagery indicating achievement motivation. (2) Need for achievement, independence, success, money. (3) Achievement motivation level. (4) Individual's goals, approach to problem solving, and initiative. (5) Work aspirations. (6) Initiative, time-bound planning, and ability to search one's environment.

The scores in the above tests reflect varying degrees of entrepreneurial potential. Those with very low scores are not admitted to the program. These tests alone, however, are not enough. The behavioral tests only explore the general entrepreneurial characteristics. But one may be suited to become an enterprising salesman, politician, or an actor but not necessarily a manufacturing entrepreneur. Hence a final selection through industry experts and trainers is necessary which explores: (1) The extent of an applicant's knowledge about and strengths and weaknesses for the manufacturing field, especially for a product he is interested in. (2) How and to what extent the training will benefit him for the manufacturing objective. (3) His own preferences among alternate opportunities, such as a secure job rather than an independent venture in sales or in manufacturing.

Training Inputs

Those who are finally selected are trained and developed through a ninety days program operated in the evening, five days a week. Evening programs make it possible for the employees, workers, merchants, etc. to continue present jobs during day-time, which is felt necessary for economic reasons, until plans for ownership ventures are finalized. The developmental inputs provided are:

(a) Achievement motivation training specially devised for industry, to develop entrepreneurial capacity.

(b) Product/opportunity guidance, so that a specific goal for an independent venture is identified towards which the trainee's motivation and energies are directed.

(c) Business management know-how, covering all aspects of how to set up and successfully operate his own business.

(d) Field experience relevant for his own project plans and for practical exposure.

(e) Project report preparation and guidance, so that in the course of the training the specific idea is developed into an acceptable viable project.

(f) Financial and industrial infrastructure assistance, on the basis of the project report, so that the new entrepreneur actually set up a unit. This can include credit facilities (see below), access to an industrial estate, electricity or other pertinent requirements.

The program for the educated unemployed is similar. The selection and the training inputs are basically the same. They differ, however, in the following areas: Programs for the educated unemployed are full-time and residential, so that their total lack of work experience could be partially compensated through 6 to 8 hours of work in factories during the day while they get training in the evening with others. They are paid a monthly stipend from Central Government funds (Rs. 250 a month, or free lodging and boarding); while for the others, a fee of Rs. 300/- is charged for three months. The duration of the program is longer for the unemployed (5 months) since they require more intensive business management guidance and as much work experience as can be arranged.

Achievement motivation training. In the first part of the program, intensive Achievement Motivation Training (AMT) is given. The AMT inputs were developed by the Behavioral Science Center, New Delhi, which follows David McClelland's approach to Motivation Training. AMT is aimed at developing the following traits in the participants, considered essential characteristics of an entrepreneur: the need to achieve; risk taking; positive self-concept (i. e. self-confidence); initiative and independence; problem solving (to approach problems in order to solve them); hopeful about the future; searching the environment, and time-bound planning.

Identifying an opportunity. In the very early phase of the program guidance sessions are held on selecting appropriate industrial opportunities for each trainee, keeping in mind the market, economic and technical feasibility, and trainee's own competence and capacity. With uncertain markets, raw materials supplies and rising prices, considerable expert guidance in choosing a product is considered essential. Once a project is identified the trainee is expected to work on it during the program to prepare a viable project report. This specifies the goal, and provides purpose and direction to the subsequent efforts to get the best out of the training for his planned venture.

Business management guidance. Perhaps the most important reason for a large number of new small scale entrepreneurs failing in the early years of production, in India as elsewhere, has been that those who set

up industries lack rounded, managerial experience in that line. In small firms an entrepreneur must do it all himself, since he cannot afford sales, purchase or finance managers to look after various business decisions. In the Entrepreneurship Development Program, once the product is identified, business management guidance on all aspects of decision-making for a small scale entrepreneur is provided. Most of the technicians and employees are totally new to the conventional management tools. It is especially so for the unemployed engineers and the educated unemployed who lack both the business and work experience. The unfamiliarity of actually running an enterprise often frightens them. Their confidence is developed by inviting trade and industry experts actually involved in decision-making in their own firms, together with business management experts from universities and colleges and successful small scale entrepreneurs, who confer informally with the trainees. The objective is to give practical, basic management guidance rather than make them experts on each aspect. Academic type management lectures kill their interest. Tricks of the trade are required and given. It is this that explains 99% attendance throughout the 90 day programs.

Field trips and work experience. As a part of practical training, a series of field trips to carefully selected industrial units are organized. Some 50 factories, small and medium scale, have been visited by the trainees. Visits to units set up by entrepreneurs of similar background make the employee, worker or merchant trainees confident that their own goal is feasible. This strengthens their motivation and desire. For many of the educated unemployed, these are first visits to operating units and a valuable introduction to how an entrepreneur and factory operate. As noted above, the new engineers and educated unemployed are put to work in selected factories for six to eight hours of daily work for 4-5 months. Strict discipline and continuous follow up ensures that the trainees gain the best out of the short duration. Indeed, even this much work experience is not adequate; but it is an improvement over pure course work.

Experience now suggest that developing new entrepreneurs can be more successfully done if the group consists of those with diverse experience, educational and occupational backgrounds. In the Gujarat program, the evening group consists of experienced employees and workers with technical skills, merchants and salesmen with business know-how, supervisors, newly graduated engineers and others. 50 to 60 individuals spending 3 months together with a common goal leads to interaction, exchange of know-how, information. The die-maker, precision tools maker, plant erector, chemist, wireman, machine tools salesman, toy merchant, electrical engineer, foreman, manager, purchasing officer and storekeeper in a typical entrepreneurial training group bring together a package of diverse knowledge and skills which cannot be easily duplicated any other way. And this complementarity also extends to meeting each other's input requirements for their proposed projects.

Entrepreneurship development is not a group therapy. Each individual to be developed is calling for individual attention, guidance and encouragement. During the training, each one is to work towards his goal of a viable project. A full time Project Leader, whose responsibility is to act as a father, priest, guide and psychiatrist looks after their individual progress and needs. Frustration may arise, motivation may fall low as project reports are delayed or business management concepts are not clearly understood. The need for running around to get raw materials, machinery quotations, market data, clearances from Government, rules and procedures etc. may cause a letdown. It is the Project Leader, himself an enterprising, friendly and likable young man, who is to provide continuous inspiration, guidance and help. Considerable improvisation is required in handling this situation. Experience in Gujarat emphasizes the fact that those in charge of implementing the program must themselves be enterprising. The development of entrepreneurs is not a routine task, it is the opposite of bureaucratic.

Financial Assistance and Support

Adequate financial assistance and infrastructure facilities constitute an integral part of the Entrepreneurship Development Program. When the training ends with finalization of a viable project report, the real task for the newly developed entrepreneur is about to begin. Unless adequate support in terms of liberal finance for the project and industrial infrastructure are readily available, the project may not materialize and the new entrepreneur remains a statistic, more frustrated now than before. The entrepreneurs being developed from previous employees, workers, salesmen or recent college graduates lack substantial financial resources of their own. Traditional financial institutions hesitate to finance them, since the entrepreneur cannot provide adequate security in terms of assets. Even if banks were to finance 70% of the investment, the 30% margin for a small project of Rs. 200,000 would amount to Rs. 60,000, which a typical trainee does not have because of his low income. Not only must he be financed, he must be financed up to 100%.

A special unorthodox scheme of finance has been evolved in Gujarat by the State Industrial Development Corporations. It provides 100% finance for plant, machinery and factory buildings to techno-entrepreneurs in general, and the new entrepreneurs developed under the Entrepreneurship Program. Finance is provided on judging "the man himself" - his competence and enterprise, disregarding his own financial contribution. A 3 year moratorium on repayment is offered to help him plough back profits. 600 entrepreneurs have been financed 100% by this Scheme (The Technicians' Scheme) in the last 4 years. And it is these Corporations which operate the Entrepreneurship Development Program. This close linkage gives the new entrepreneur access to full and quick financial assistance; it acts as a significant motivating factor in satisfactorily completing the training, and assures that training programs can

result in an increase in actual manufacturing units. Elsewhere, in India and abroad, entrepreneurship programs have been undertaken by government departments or academic institutions independently, without a close liason with financial institutions. They may have developed many entrepreneurs, but only a few industrial units have come up.

Results

So far [March 1973] a total of 293 new entrepreneurs have been trained. Of the 242 employed trainees, 109 have already set up their industrial units while additional 36 have their project approved by the financial institutions and are awaiting arrival of machinery or completion of factory buildings. 51 of the 293 newly developed entrepreneurs have been new (unemployed) engineers. The task of developing them has been far more complex. Out of these, 15 have already set up their own factories and 20 are about to do so within 3 to 5 months. Even here the results are 70%. These are even more significant for they raise hopes that a large number of unemployed engineers could be productively self-employed. In all, 195 new industrial factories would have come up by middle of 1973 - a satisfactory 67% success. They will be mainly in the engineering, chemicals, plastics and electronics industries. The total investment in the projects would be Rs. 37.6 million with an annual output of Rs. 46.4 million. These new entrepreneurs would employ an average of 17 workers, creating 3315 new jobs with an average investment of Rs. 14,000 per job.

The real success of these entrepreneurs and hence of the program must be judged after a few years of production experience during which their enterprise and business competence will be tested. Follow-up reports indicate that on average these entrepreneurs have reached break-even points in their ventures earlier than normal for small scale units and are able to manage well despite shortages, bottlenecks, uncertainties and fluctuations in the economy.

Characteristics of Entrepreneurs. Of the 293 selected for training, 193 college graduates accounted for 66% of the total. Of the rest, 34 had not finished high school, 43 had high school degrees (matriculates) and 23 had entered but not completed college. How many of each group actually set up factories? Out of 193 graduates selected, 63% set up factories as against 70% of those from high school or below. Commerce and Engineering graduates are more likely to develop into manufacturing entrepreneurs than the Science and Arts graduates: 90% of the Commerce graduates set up factories (though their number is small) and 70% of the engineers. On the other hand, only 51% of the Science and 56% of the Arts graduates will be setting up factories. It appears that the Commerce education which deals with areas related to business better equips the young men to move into their own business. Those with a Science background (chemistry and

physics) seem to acquire attitudes, skills and outlook more fit for research, laboratory tasks in controlled environment, or a secure job in a drug store, and are less likely to develop as entrepreneurs. Those with less education seem to perform as well as graduates. Lack of education may force people to take up jobs at an early age and thereby develop experience, skills, frustrations and hence motivation to become independent. They do not have many alternate opportunities, and hence are more committed to ownership goals.

Those in the age group 36-40 have performed best, with 81% of those selected reaching their goal of establishing a firm. These are the ones with 10-15 years of experience which offers skills, sounder opportunities, confidence, and a stronger desire to become independent and leave the boredom of routine jobs. Performance is good (63-76%) in the age groups of 26-35 also; their years of work experience develop sufficient technical or business familiarity. More significantly, the early job experience at a young age indicates to many the poor economic prospects in employment and, with relatively fewer family responsibilities, provides the motivation to decide early in life for taking calculated risks of independent enterprise. At an older age, such as 41 and above, these decisions are difficult to implement, as seen from the drop to 33% who take the risk. Even a younger age group of 21-25 offers adequate entrepreneurial material (64%) in a country where jobs are scarce and salaries are low, forcing the young to increasingly think of self-employment. That only one of the six in the very young group of 18-20 had started a firm is not surprising: inadequate experience, and a need to have an early income from the first available job are sufficient reasons.

[Extracted from "Entrepreneurship Development: A Technology for Employment and Growth," a paper presented to the Ford Foundation Seminar on Technology and Employment, New Delhi, India, March 21-24, 1973.]

Changing Theories of Management

William Boothe

[Traditional theories of management for business firms, as for other large organizations, are basically rules for establishing an orderly hierarchy of authority. Modern findings in the behavoral sciences point to different approaches which should do more to bring out the best in employees for the benefit of their employing organizations.]

Since the 1930's, systematic examinations of management problems have gained significant momentum and have progressed from a non-sophisticated to a relatively sophisticated study. In such a transition, and particularly in one that involves human nature as a focal point, we find the development of diverse schools of thought, with countering theories, claims and research results. We shall begin with the traditional or classical theory, and go on to a few of the more modern modifications and counter-theories.

Classical Organization Theory

Many of the rules for organizing a hierarchy of authority were originated by the Romans, nurtured by governments, ordained by the church and saluted by military tradition and practice. The impact of the Industrial Revolution entrenched them in factories and other large organizations, private or public, throughout Western society. Let us examine some of the classical rules of formal organization, and note along with each measure some critical comments in the light of modern findings in the behavioral sciences.

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1. Someone should be responsible for supervising all essential activities. (While this rule may be effective in an emergency, research of the past twenty years points to the utility of shared leadership.)

2. Responsibility for specific action should not be duplicated or overlapping. (Completely independent duplication of effort may well increase waste. At the same time, the freedom to duplicate is basic to the competitive system. Three planners instead of one will not only provide us with a variety of creative choices but increase the possibility of a solid backup system.)

3. No one position should have too numerous or complex duties. (While this rule may be economically sound and at times a stimulus to efficiency, it is also contrary to what we know about the stimulative effects of job challenge and job opportunity in producing job interest and job involvement.)

4. Job responsibility should be written and clearly understood by job occupants. (This may contribute to understanding, but it opens the possibilities of jurisdictional dispute, concerns about responsibilities rather than objectives, and arguments about words instead of work.)

5. Authority to make decisions should be commensurate with responsibility for the decision. (This statement ignores the fact that much authority resides in a person because of the esteem his associates have for him, irrespective of his position in the hierarchy. The rule also promotes irresponsibility, as people hide behind the statement, "I did exactly as I was told.")

6. Authority should be delegated so that decisions take place as close as possible to the point of action. (If this rule could be consistently applied with the preceding rules, it would conform to the suggestions of behavioral science. However, the hierarchical organization which must be established as a consequence of the preceding rules pushes decision making at least one echelon higher than the point of action.)

7. Executives should have no more than five to seven subordinates reporting to them. (This only makes for more hierarchical levels over a given number of workers. Messages initiated at the bottom of such a many layered organization are unlikely to reach the top without distortion.)

8. Every occupant of each position should know to whom he reports and who reports to him. (The following statement was made by an executive officer of a large corporation: "Chain of command looks good on paper, but it is impractical. It is supposed to tell who takes orders from whom. More often, it is the subordinates who are in better positions to make decisions affecting their own behavior than their superiors.

In practice, this subservient plan of organization is unlikely to work well if followed. More often than not, it is not followed. ")

"Scientific Management"

The traditional rules of classical organization theory were refined in the 1920's by Frederick W. Taylor, who is considered to be the father of time and motion study. The systematic analysis of jobs, the precise measurement of the motions and timing of workers performing particular tasks, followed by prescriptions of just how each job should be done--this has been called scientific management. While most of these theories appear to be reasonably logical, they are predicated on some questionable assumptions about human behavior. They assume that workers must be persuaded, rewarded, punished, controlled and directed, if coordination of effort is to be achieved. With millions of employees reduced to mere automatons, or mere extensions of machines, Taylor concerned himself with individual efficiency ratings, arm movements, muscle fatigue, production rates, and largely ignored individual needs. Thus, the theory of scientific management grew out of the precepts of classical organization theory. There are several apparent criticisms of scientific management:

1. It assumes that there is always one best way to perform any task. This assumption is obviously not true if we allow for individual differences.

2. Scientific management ignores individual differences - in fact, differences are looked upon as being errors. Scientific management can be described as prescriptive and mechanistic because it describes how things ought to be done without considering the differences of the people expected to accomplish the task.

3. Scientific management ignores the complex behavior of people in an organization; it makes erroneous assumptions regarding the basic principles of human learning and motivation.

There is no doubt that autocratic suppression and an unrewarding "tick tock" routine plays havoc with the morale of the worker. There were inevitable reactions as employees soon realized that increased production not only meant increased speed and earnings, but the added possibility of a saturated market and eventual layoff. The formation of unions, work slowdown, and featherbedding techniques, are obvious examples of reactions by the worker. The reaction on the part of management was a developing awareness that sole reliance on scientific management principles caused them to fall far short of their production and profit expectations. This growing discontent led management to look enthusiastically in the early 1930's at very promising studies that were being carried on in a small electrical equipment plant in Chicago. These studies represent the birth of the human relations movement.

The Human Relations Movement

The Hawthorne plant of the Western Electric Company, which manufactures equipment for the telephone industry, began experiments to determine the relationships between physical conditions of work, such as the level of illumination, hours of work, coffee breaks, etc., and production output. The results, however, did not validate any reasonable physiological relationships. Instead, the investigators found that the relationship was obscured or confounded by numerous other psychological variables.

The basic experimental design was as follows. Six girls were chosen from a large manufacturing department. They were purposely selected as "average" workers and their task was to assemble telephone relays. Throughout the study the experimentors changes the illumination, rest breaks, and pay schedules in both positive and negative directions. Contrary to original expectations, production continually increased, even with poor lighting and reduced pay. When questioned, the individuals in the experiment were not sure why they had continued to perform at high levels, but several points eventually came out in the interviews.

1. The girls like to work in the "test room." "It was fun."

2. The change in supervisory control allowed the girls to work with less anxiety and to converse freely. In the pre-experimental work situation, conversation had been restricted.

3. The subjects knew that they were the focal point of an experiment, and hence felt the company had a personal interest in them.

4. The girls became "involved" as the superintendent solicited their views of changes or proposed changes in the experimental assembly and procedures.

5. The experimental group developed strong cohesive bonds as the girls continued to associate socially after working hours.

6. The group developed leadership and a common purpose. An ambitious young immigrant girl became the leader of the group, and the group developed the common purpose of effecting an increase in the output rate.

The Western Electric researches contributed a major step toward a concern by management for human relations. They offered simple and relatively clear ideas for the study and understanding of human

situations in business. They caused management and researchers to realize that whether a person wholeheartedly gives his services to a group depends, in large part, on the way he feels about his job, his fellow workers, and supervisors. In short, it depends on the meaning for the worker of what is happening about him. Above all, the researchers focused attention on the worker as a social animal who must be treated as such.

The human relations movement has had a dramatic effect on the practices of American industry. In retrospect, we can suggest that industry overreacted. Emphasis on the social system, on fringe benefits, and on the physical surroundings in the work environment are all reactions that are classified as "human relations." In a number of companies the effort was made to bend over backwards to get along with everybody, and make the worker "happy" and "comfortable." Current behavioral science findings, however, suggest that getting along is not necessarily the most important aspect of being a supervisor or manager. The goal is to get a job done with full commitment, and commitment then becomes that which helps people get along with each other. Commitment increases as the employee's perception of the significance of his task increases.

Therefore in opposing classical organization theory the human relations theorist also makes faulty assumptions regarding the motivation to work. Not only does the human relations theorist have basic misconceptions regarding motivation, but he couples this with a disregard for effective principles of economics and technology. As a result, the approach is ineffectual and subsequently squanders organizational resources.

Theories X and Y: Management by Objectives

The author of The Human Side of Enterprise, Douglas McGregor, was the head of the school of industrial human relations at the Massachusetts Institute of Technology when his book was published in 1960. "We are becoming quite certain," he stated, "that under the proper conditions, unimagined resources of creative human energy could become available within the organization setting." After stating management's task in organizing the elements of productive enterprise, i.e., money, materials, equipment and people, in the interest of economic ends, McGregor develops his well-known "Theory X" and "Theory Y."

Briefly, "Theory X" exclusively relies upon external control of human behavior. Like classical organization theory, "Theory X" is based on the belief that the average man is by nature indolent, irresponsible, resistant to change, gullible and certainly not very bright. These assumptions prompt hard management through the use of coercion, threat and tight control. In contrast with "Theory X", McGregor suggests a different theory of managing people based on more adequate knowledge about human nature and motivation. He refers to this as "Theory Y." According

to McGregor: "The essential task of management is to arrange organizational conditions and methods of operation so that people can achieve their own goals best by directing their own efforts toward organizational objectives." Primarily this process involves creating opportunities, releasing potential, removing obstacles, encouraging growth and providing guidance. It has been referred to as "Management by Objectives" in contrast to Theory X's "Management by Controls." Thus, management by objectives requires that subordinates be brought to share the objectives of their organization, so that they will want to make their own efforts to attain them.

Under Theory Y people are not viewed as being passive by nature. Rather, if they are passive, it is probably a result of their experience in organizations. The capacity, readiness and need to assume responsibility are waiting in untapped reservoirs of potential in most people. McGregor warns, however, that there are many formidable obstacles to overcome before people in industry can respond to Theory Y management. They are accustomed to being directed, manipulated and controlled. Management, however, must reverse this "conditioned" state so that people can respond positively to Theory Y management by increased production and desired behavior.

Chris Argyris of Yale University, on the other hand, warns that: "there is a lack of congruency between the needs of individuals and the demands of the formal organization." These differences result in frustration, failure, short time perspective, and conflict. The negative factors progressively increase as you go down the chain of command, as directive leadership increases, as management controls are increased, and as "human relations" programs are undertaken but improperly implemented. Argyris states: "People will adapt to the frustration, conflict and failure by engaging in one or a combination of these kinds of activities: a) Leave the situation (absenteeism). b) Seek to move up the organization ladder. c) Become defensive through such techniques as grievances and daydreaming. d) Become apathetic and disinterested in the organization and what it is doing. e) Organize informal groups to sanction (through affiliative behavior) the various defenses in c and d. f) Formalize such informal groups into trade unions and similar groups. g) De-emphasize creativity and self-growth and emphasize monetary and material rewards."

Like McGregor, Argyris believes that each individual strives for wholeness, integrity and the realization of self-perceived potential. The harnessing of such drives to the achievement of organization objectives is again cited as the crucial yet frustrating task of management. A manager must strive for the following: 1) His goals must be precise and clearly understood by the worker (as with "management by objective"). A worker should have a part in determining both his goals and the paths to the achievement of the goals. 2) The

worker must perceive his task as one which makes a significant contribution to organization purpose. 3) He must feel that others consider his task as noteworthy or significant. One guideline that Argyris offers is to determine the amount of risk involved in any task. Unless there is a feeling of personal risk involved, the task probably does not have enough responsibility or significance to utilize the potential of self-actualization.

Motivation

Of all the areas of concern to the manager, the subject of motivation is probably the most difficult and complex aspect of the management task. But it is also the area that has the potential of the highest payoff. Much of the recent thinking about motivation in the behavioral sciences stems from the work of Abraham Maslow. Maslow suggests there are five levels of needs which all people share, and these needs are in a prerequisite order. That is, a lower need predominates until it is fulfilled to the satisfaction of the individual. The individual then turns his attention to the next need in the ascendancy, and so on. A critical point here is that a satisfied need does not motivate people.

Hierarchy of Needs

The five levels are identified as follows:

Physiological Needs: the need for self-preservation - for warmth, food, shelter, protection. Gandhi put it best when he said, "Even God himself

can only talk to hungry men in terms of bread." If man is threatened in this area, his attention turns to this need until it is satisfied.

Security Needs: these include the stability of job and income, freedom from accidents, and freedom from an otherwise threatening environment. The security is of greater concern to the manager, since once an employee achieves a comfortable economic level he wants assurance that he will stay there. He doesn't want to worry about loss of job, income or home. But it would appear that we have generally overemphasized income: after one reaches his "comfort level," additional money does not seem to be the motivator it was before reaching that level.

Social Needs. Maslow called this love. This need of man as applied to business could be called "belongingness" or "membership." Men want to belong to a group with which they identify. They want to be accepted by the group and to be an important part of its operation.

Psychological Needs: Maslow called this esteem. It has to do with one's ego, such things as status, recognition, prestige and a high evaluation of one's self.

Self-Actualization: Sometimes called self-fulfillment, it involves mastery of the job and being as much as you can be through your work. Today we call it "Doing your thing". Man has the need to feel that he is making progress toward a goal which is important to him. He wants to feel that through his endeavors he will reach full potential. Essentially this need has to do with the challenge of his work and how important and worthwhile he believes that challenge to be. As does McGregor, Maslow assumes that each person will attempt to "actualize" or achieve his perceived potential. People who have reached a satisfactory level in these needs show the fullest and healthiest creativeness.

In the application of Maslow's concept there are several basic factors that must be considered. If the economic factors, the physiological and security needs are not satisfied, man is not very concerned with the higher needs. But employers can't control everything; we can only hope that our employees have sufficient sense to keep their domestic economic house in order. If one chooses to live above his income, management can do little for him if the income is fair in the first place.

If an employee has reached his "comfort level," it is not fair to say that his economic needs are completely satisfied. A need is seldom completely satisfied. However, once the worker feels that the wage he is receiving is consistent with the type of work performed, continued attempts to motivate him to high levels of performance on the basis of income alone can meet with less than full success. The manager must also recognize that no two of his people are alike and therefore have different need intensities. Experiences early in life will certainly

influence the importance of these needs to the worker. In many families, for example, our young people today seem not as concerned with economic needs as their fathers. Assuming Maslow's concept is valid (and his thesis is generally accepted by behavioral scientists) management can use money to help people fill their physiological and security needs. But it requires effective leadership which can help people find a feeling of membership and belongingness to fill their social and psychological needs. Beyond that, being meaningfully engaged in the achievement of goals and objectives helps a man to find self-actualization from his work. The greatest opportunity is in creating the conditions for self-actualization. An effective manager attempts to construct that combination of money, leadership and possibilities for self-actualization that is most meaningful for each of his subordinates.

[Extracted from course notes prepared in 1975 for a leadership seminar given by the World Bank's Economic Development Institute. Based on "Behavioral Science Techniques for Management---Where Leadership Leads", prepared for the Xerox Corporation in 1969.]

Japanese Methods of Industrial Management

V. V. Bhatt

[Industrial management in Japan has unusual features which deserve to be better understood. Two of the basic characteristics are decision making by concensus, and lifetime employment in a large company.]

The great successes of Japan in its industrial development, particularly since World War II, have attracted interest in the way in which its industrial establishments are organized and administered. The large Japanese firms have developed certain practices that differ quite a bit from traditional Western practice and theory. Some of the newer Western thinking, such as that of Douglas McGregor [see Theories X and Y in preceding article], can be interpreted as explaining why Japanese practice should elicit productive behavior from workers and professional staff. But for the most part Japan has gone its own way: its methods are not generally studied in management courses in Western universities, nor in those of developing countries, and the lessons that might be drawn from Japanese experience have yet to be fully explored.

In a brief description of methods used in the large companies in Japan, one striking difference from practice elsewhere is in the style of communications that affects relations among the educated and less educated, the technicians and laymen, bosses and subordinates. In small firms the relations among these groups can be informal; in large firms they are expected to consult each other systematically and listen to one another

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with attention, to avoid authoritarianism or arbitrary unilateral orders. This self discipline is necessary for carrying out the Japanese way of decision making by concensus.

This does not mean seeking a consensus by accepting as solution to a problem the lowest common denominator - the least demanding items on which all can agree. Rather, the effort is to seek all pertinent views so that they can, after adequate discussion, contribute to a decision which all parties can understand and carry out as a result of their participation. It is really an art of making effective decisions. What is important in a Japanese business enterprise is not only the answer to a question but the question itself. What they spend much time on is on defining the question - a process in which all managerial and other cadres are involved. The result is that the problem is understood in all its implications, and the alternative solutions and action programs are explored and examined. Once this is done, the decision becomes almost obvious, and so does the action program, to the relevant personnel. Thus, taking a decision and acting on it become two simultaneous processes rather than two distinct stages. Normally, elsewhere, a decision is taken and then it has to be "sold" to the people who have to act on it. In Japan, conflicts are ironed out at the stage of decision making, and the entire institution identifies itself with the problem and its solution. This promotes harmony, a sense of participation and hence a sense of identification with the interests and performance of the entire institution.

Behind the willingness of workers and staff to interact in this way lies an unusual structure of relationships within a large company, having the following characteristics:

(a) There is lifetime employment once a worker is employed, and his emoluments and their progressive increase are fixed and known. Japanese tradition divides the work force into three catagories: Manual Worker, Clerical Worker, and Manager. For each category, entrance pay is the same for everybody and so is the entrance age - 15, 18, 22 respectively. Progression in pay as well as title are then automatic - for manual and clerical worker until retirement, for managers until age 45. Pay and title depend on the length of service.

(b) Labor costs are still flexible, as there is a category of temporary work force which can be laid off without any notice. Further, excepting for top management, there is compulsory retirement at age 55, after which if one is employed he becomes a part of the temporary work force.

(c) The non-wage benefits are almost as important as wage benefits; but they are tailored to the specific needs of each employee group - young women workers, old male workers, people with large families, the unmarried, or older couples whose children have grown up.

(d) Top management takes the task of manager development, manager

selection and manager placement very seriously. A person enters the work force at the age of 22 after completing his university education. The first two years of his service, he is put in direct and intimate contact with a member of upper-middle management - a person who has not been promoted to a top management job by the age 45 and thus has no chance of further promotion in rank. This "godfather" tries to understand the employee's needs, requirements, aspirations, motivations and competence and helps him in a number of different ways; he is not his direct supervisor and hence the two develop a bond of mutual confidence without much fear. It is this system which enables the top management to select the best employees for top management jobs at the age of 45; those who are not so promoted still continue in service till 55, after which they are transferred to the top management of a subsidiary or an affiliate.

(e) With this measure of certainty and security assured to the employees, the mechanism for making the worker take responsibility for continuous improvement of his job, group performance and tools is what the Japanese call "continuous training." This Zen approach to continuous training emphasizes the fact that learning is a continuous process. [Zen Buddhism - the master induces the young aspirant to seek truth for himself]. This self-improvement through the process of always learning is institutionalized in the weekly training session, in which the workers of different skills meet and focus on the ways of improving total performance. This creates a habit of evaluating one's own performance and of the performance group - which leads to a stronger sense of community, a sense of identification with the institutional performance, and a greater receptivity to innovative change.

Although the industrial engineers in Japanese industry use the same methods, tools and techniques as the Westerner to study and analyze work, the Japanese industrial engineer does not organize the worker's job. When he has reached the point at which he understands the work, he turns over the actual design of jobs to the work group itself. In fact, the industrial engineer begins to work with the people who (as "permanent" employees) will have to do the job long before he finishes his analysis. When he has finished his analysis, the synthesis will essentially be done by the work group itself. The industrial engineer continues his activities, but he does so as "assistant" to the work group rather than as an outside analyst. The Japanese worker very largely also takes responsibility for improving his tools. Machines in modern industry are, of course, designed by the engineer; but when a new machine or a new process is being introduced, the workers are expected to take an active part in the final adjustment, the final arrangement, the specific application of machine and tools. In many businesses, the work force actually participates in machine designing. In the West, the industrial engineer starts out with the assumption of resistance to

his approach by the employee, whether in manual or clerical work. In Japan the industrial engineer tends to complain that the employees expect and demand too much from him. This continuous learning approach operates right up to the top management: a company president who takes a correspondence course in computer programming is fairly common.

Some of the features of the Japanese system were tried out independently elsewhere, and with success. Examples include the Zeiss Optical Works in Germany under Ernst Abbe (1840-1905); and the IBM (International Business Machines) in the USA under Thomas J. Watson, Sr., the company's founder and for many years its president.

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Editorial Comment: The Japanese managerial methods described here have been brought to a high level of articulation during the period of very rapid and steady economic growth in Japan since World War II. In these conditions they have proved their ability to stimulate substantial rates of increase in industrial productivity in a very practical way - given the Japanese cultural setting. What must also be considered is, first, whether they would be equally effective in arousing employee motivation in other cultural settings; and second, the extent to which they may be dependent on an environment of continuous economic expansion. In a period of recession or stagnation, a company's obligation to maintain and slowly augment the incomes of a permanent and steadily aging workforce could appreciably raise its unit costs of production. These questions cannot as yet be answered with any finality from experience. Certainly the Japanese methods and their results to date present an important contribution to management theory and practice; they will need to be better understood, and tested in a variety of conditions.

Development of Case Studies for Teaching Management

B. G. Shah

[The reliance on case studies from actual company experiences for the teaching of business management, a method used prominently in the Harvard School of Business Administration, requires the development of materials from the environment where trainees will be working. This article describes how to go about developing such materials, and related problems.]

Management has developed into a profession. Its practitioners need training no less than those of medicine or law or engineering. Traditionally, a management school aims at training professional managers for business, and much work has been done to develop management into a distinct field of research and teaching. But it is widely accepted that the goal of management education is not that of producing scholars of the subject; its educational goal is to help the trainees to acquire facility to act in the face of uncertainty and risks. The use of case studies has a great potential in achieving that educational objective. They make it possible for the trainees to increase their "vocabulary of experience", and to draw on that learning from others' experiences in dealing with concrete problem situations which they may face in the course of their career. This paper discusses the process of developing a strong collection of cases for use in the teaching of business management.

The Process of Case Development

A case course is much more than a mere collection of cases. Case studies must be relevant to the

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course objectives. A good case course should meet two tests: it should increase the trainee's background of exposure to second hand experience which he can draw upon in dealing with the decisional situations that he is likely to face; and second, he should gain an understanding of the relevant concepts and techniques and their application in the resolution of problems. The first essential step in case development is therefore to answer the three questions: (i) who is the target trainee of the course? (ii) what are the positions he should be trained for? and (iii) what are the kinds of decisional situations he is likely to face in such positions? Answers to these questions will determine the course content and its teaching objectives, the sequence of the course and course sessions, and the weights to be assigned to different topics of the course. I would like to illustrate the above process by reference to case development work for a case course in Credit Management that I developed for a large nationalized commercial bank.

The target trainees were branch managers and officers in the advances department of the head office of the bank. I found that the mix of advances and job responsibilities varied widely between branches, depending upon their size and location. So I first identified a group of trainees who had a broadly similar mix of procedures and responsibilities in order to design a course that was related to the jobs of the trainee group. The next step was to analyze the kind of decisional areas that the trainee group would face so as to draw the specifications for case studies that would meet the course objectives. I also found that a majority of the trainees had no background in management and financial accounting. Accordingly, cases written to give trainees an understanding of basic accounting concepts and methods, and cost concepts and their applications in making credit decisions, were included in the course materials. This process of developing a course framework lent a direction to the work of case collection and preparation of technical notes to achieve the course objectives.

Case Leads

After the case situations that will meet the course objectives are defined, the next step is to find leads for the collection of case materials. These can be developed in several ways. Case leads can be found by a careful perusal of company reports, reports of study groups, commissions and committees appointed by the government or associations of trade and industry, histories of business houses, research reports recording the finding of problem oriented researches, business journals, and such other published materials. When the case writer has some idea of the kind of problem situation he is looking for, a lead can be developed by identifying companies that are known to have experienced such a problem. (For example, I was looking for a case study on the problems of amalgamation of banks; I knew of a bank that came into being as a result of amalgamation of four middle sized banks;

I developed a lead for my proposed case study through a friend of mine who knew the top executive of that bank.) Alumni of a business school are a rich source of case leads. Most management schools organize programs for practicing executives, and the alumni of such executive development programs are a particularly fruitful source of case leads on the kinds of problems they are facing in real life. Our experience is that the potential of this source for case development work is not fully exploited. Much depends on how far the administrators of the management schools have communicated their needs for case collection to their alumni and the willingness of the alumni to commit their time and effort to support and supplement the case collection activity of the school. A word of caution is necessary: alumni who support the case collection activity of the school must do so with the knowledge and consent of their top executives, so that their case collection activity gets legitimized and contributes to good relations between the school and its alumni.

Yet another source of case leads is the project research work undertaken by trainees as part of the course work. Such problem-centered project reports provide a good basis for developing diagnostic and prescriptive depth case studies of real life management problems. Similarly some excellent case leads can be developed from the research studies made by faculty as a part of the process of collecting research data to construct and/or test hypotheses, or to fulfill a thesis. Also, some of the best case leads are developed out of the consulting activity of the faculty of the management school. A consulting assignment generally involves a deep search for the real problem, and prescription of a course of action to resolve that problem; clients cooperate in the investigation of the problem, and provide the data relevant to its analysis.

Before following up on a case lead by a visit to the company for field work, it is a good practice to first know all you can about the company, its product-market data, the industry in which it is working and its problems. A good deal of such information is available in published sources such as the annual financial statements of the company, industry studies, government policy statements, etc. Invariably, company executives are more willing to cooperate when they find that a case writer has taken pains to know as much as he can about the company and its problems. It is also desirable that a case writer prepare a written specification of the case study. Such a specification would include a statement of the teaching objective(s) of the case, a description of the decisional situation which is the subject matter of study, the data that might be necessary for a meaningful analysis of the problem situation, and the possible sources of such data. While such a specification should provide direction to the field work, it must not be allowed to structure the work to an extent that one sacrifices reality to the specification.

For a case lead to be productive, it is advisable that the case collection work start with an appointment with a responsible top executive of the company. It is not unusual that a company executive does not fully comprehend what he is getting into in agreeing to a preparation of a case study on the company problem. It is a good practice therefore to explain to him what a case study is (unless he is an alumnus already exposed to the case method) and the kind of problem and data you are looking for. It is also our experience that people at lower levels of organization cooperate more fully in the case collection work after it is cleared with the top executives. It is important to ensure that a company does not feel pestered by several people simultaneously doing case collection work with it. Before an approach is made to a company one should check whether anyone else is working on another case study in the company or recently did so, and what have been the experiences of the previous case writers with that company.

Case Writing

It is usual to begin a case with a description of the situation or an event or incident which is the theme of the case study. A case may also begin with the statement of a problem as perceived by the chief character in the case, or by giving a lead or clues to the identification of the real problem. Depending upon the case objective, a case writer has to decide on how far to obscure the real problem. The line between constructively obscuring the real problem and leading the participants up the garden path is indeed a narrow one. Since real life management problems are often obscured by outward appearances, the case study will be artificial if the real problem is too evident, and the diagnostic element of the case study session will be lost. If, however, the real problem is so thoroughly concealed that the participants could not reasonably be expected to find it, the object of the case study is not likely to be achieved. A golden rule in writing details around the real problem is to aim for the least degree of concealment necessary to achieve the course objectives. In practice many managers tend to focus their attention on some detail and miss the real problem altogether, and a judicious introduction of "red herrings" into the case study can effectively highlight the dangers of this tendency. A good measurement of manager's perceptivity can be the skill with which he spots the red herrings and the real issues.

The point can be illustrated with some concrete problem situations I came across in my case collection and consulting work. A large textile mill asked us to look into its losing operation. The top management of the company was of the view that its real problem was inability of its distribution channel to market products that were high contributors (to profit) and an inadequate flow of market information. Our study revealed that its real problem was that of active search for an optimal product mix to satisfy both marketing and manufacturing constraints and yield a contribution high enough to absorb its comparatively high

fixed costs. Another case deals with a dissatisfied management trainee in a bank. The case describes in detail his growing disillusionment with the management, and vice versa. Our study showed that the problem was neither with the training program nor the reliability of the selection test but in the inability of the trainee to relate his training to his perception of his job, which influenced his communication and behavior with management.

A case writer has to decide on which details to present in the case, and how much weight to give them. The case writer's judgment on what details are relevant to the case analysis depends to a large extent on how much effort he has put in to understand the basics of the industry and the problem he is working on. But the best judge of what are relevant details in the case situation are the characters involved in the case study rather than the case writer. The question always arises when in real life a decision was arrived at without use of all the information that may seem relevant to the case writer. Take for example, a case study on planning and policy where the decision maker had not made worthwhile use of the relevant environmental data. Should the case writer include environmental data not used in actual decision making process in order to achieve the teaching-learning objective of the case? Loading a case with too many details distracts from its value. The case must have just enough details to achieve its teaching purpose. For example, in a case study on the performance appraisal of a bank, the addition of an appendix describing various types of deposits, advances and remittances instruments and branch administration methods proved useful to the analysis of the case by a predominantly non-banker group. It is also important that the details must be accurate, factual, and consistent. Incorrect information on yarn realization from a pound of cotton in a case study on the appraisal of a loan for the purchase of a spinning machine, for example, led the class to turn down the proposal when in fact it was (properly) sanctioned. Checking on details is particularly important as well as tricky when these are included in order to disguise the identity of the organization.

Confidentiality and Disguises

Another problem the case writer encounters in the process of case development is to decide on how to disguise the identity of a company in a teaching case. One may conceal the identity of an organization by disguising the names of companies, persons, products, places and figures. In choosing a disguised name, care should be taken to see that a company with a similar name does not exist; it is my experience that this can happen despite all the care one may take. Disguise of an industry however should be avoided. Each industry has its own technology and set of commercial and economic problems, and the entire case discussion would take place in an unreal context when the industry

is disguised. Sometimes a company wants its product to be disguised. In that case, the product-market characteristics must still be described in sufficient and relevant detail to preserve the real-life flavor. It is usual to disguise the balance sheet and the profit and loss figures by applying a constant multiplier or a deflater; but it may be difficult in such a case to preserve the basic behavioral relationship among different types of costs. Disguise of balance sheet and income figures usually requires appropriate revision of other related figures on investment, scale of output, sales, working capital, etc. Even the disguise of a place can create a problem when there are special environmental features that would be valuable for trainees to learn about.

Despite these problems, every care must be taken to preserve the confidential nature of information gathered during case collection work. The case writer must disguise the case in the manner agreed upon with the company so that its identity is kept confidential. A case writer should never share the information gathered from one executive or organization with another one. Even a single case of violation of confidence can damage the reputation of his school and the trust that it may enjoy with the world of management. A case writer should be required to obtain from a responsible company executive a signed release of the text of the case. There are two reasons for this: The first is to protect the company itself from the misinterpretation of facts or from the uncontrolled use of material given in confidence; the release card assures the company that the case will be used only in the form in which it was released. The second purpose is to protect the school by providing written evidence that the permission has been granted to use the material in question.

The problem of quid pro quo. The executives who throw open their companies for case writing must do so in order that others may profit from their own experiences. They should understand that neither the case writer nor the school he represents makes any promise of "quid pro quo" for the time and effort they commit in assisting case collection work. Expectations that case collection work would lead to free consulting help or appraisal of company decisions should be discouraged. Many small businessmen do have such expectations: a technician entrepreneur, who had cooperated in developing a case study on his firm, asked me if I could prepare a cash flow forecast and help him negotiate a loan limit with his banker. Another small entrepreneur manufacturing electronics equipment wanted the case writer to represent his problems as described in the case study to his bank and the government.

There are, however, several ways in which executives may benefit from case collection work. First, an executive derives a great deal of benefit from the way the case writer structures his approach to the problem under study. Company executives also get opportunities for self-evaluation and introspection in the course of their association with the data collection work. Depending upon how knowledgeable the case

writer is, case collection work may also generate new approaches and alternatives for the resolution of a problem, and these may be later evaluated and pursued by the executives. Further, a business may gain from hiring young managers who have been trained (with the case method) to make decisions on real life managerial problems.

How to bring realism into discussion of a case study. The claim that the case method brings realism to the discussion in a classroom has been contested. It is argued that case discussion in a classroom does not involve the pressures or impose the penalties of decision-making in real life. To bring realism to bear on the case discussion in the classroom, therefore, two things can be done: the students must be pushed into taking a decision on the case situation. After they have taken the decision, they may be informed of the actual decision taken in the real life, and its sequel, which will make it possible for the students to measure the results of their actions. The other thing that can be done is to write a series of cases such that each subsequent case in the series deals with the consequences of decisions taken in the previous case in the series.

The maturing process. Rarely does a case turn out to be perfect the first time it is written. It has to go through a certain maturing process. The first stage begins with the preparation of a teaching note on the case study. This often brings out the strengths and weaknesses of the case study, and points to the lines along which it needs revision to achieve its teaching objectives. Free and frank discussion of cases in a faculty seminar could also generate useful feedback on the improvement of case studies. However, if case seminars are to be fruitful sources of feedback for revision, there must be willingness on the part of faculty to offer and take criticism. Some useful directions for revision of the case study also emerge from its discussion in classroom situations. The case writer should make detailed notes of the classroom experiences in using the case so that he may be able to evaluate how far the case achieves the teaching-learning objective(s) with which it was written.

Case Development and the Institutional Environment

The case method demands a certain kind of institutional environment for its effective application. These demands result from the fluid nature of management as a field of study, and the educational goal of a school of management. Even now many academicians have some reservations in accepting that management is a field worthy of research and teaching, and indeed that the practice of management really can be taught. The concept of management and the pedagogy of training decision makers, therefore, deserve constant exploration and experimentation. The authorities must accordingly create an environment that is conducive to such experimentation in research and in teaching. The educational goal of a management school is not that of producing 'erudite' or 'learned' men,

but practitioners of management who are experiencially and conceptually equipped to act in the face of uncertainty and change. The goal of a management school is to develop and impart the knowledge and skills required for the resolution of real life managerial problems. To achieve that goal, it is necessary that the school must build bridges between the academic and management worlds.

This, however, is not an easy task. The academicians believe that management is at best an art, and requires sound common-sense and skills in manipulation rather than rigorous conceptualization. This belief is to some extent encouraged by the fact that quite a few businessmen have had little formal education or training. Generally academicians are reluctant to descend from the realm of logical concepts and thoughts to the study of actual decision-making processes in an uncertain world. Practicing managers, on the other hand, are unable to comprehend what academicians can do to help them manage their affairs. Their perception of academicians is that of persons who live in an ivory tower, revel in building logical and neat models, and are oblivious of the different constraints and uncertainties that obtain in the real life world of management.

Case development work cannot make much headway unless the authorities of a management school accept that its goal should be that of producing practitioners of management, and encourage its faculty to take effective steps to build bridges between the non-communicating academic and business worlds. It was for this reason that our Institute organized programs for practicing executives before starting a two-year full time residential post-graduate course in business administration. In my efforts at building a management program in a university department elsewhere, I organized a conference of the opinion setters in local business with the faculty members of relevant disciplines. This contributed to building up a mutually supportive relationship. The businessmen gradually opened up their firms for case and project research, granted donations to support various activities of the school, and subscribed to the management development programs organized by the department. Similarly, I organized a research and development service at the University of Lagos, Nigeria, to serve as a link between the faculty and the business community.

The case method places unusual stresses on the faculty of a management school. Its teachers encounter a "crisis of identity." The business world rejects them as "impractical", "theoretical", and "model builders." Their peers in the academic world reject them because case research and applied research work involving applications of existing knowledge in resolution of business problems do not contribute to the extension of frontiers of conceptual knowledge. The teacher in a management school is torn between these conflicting pulls. He desires, on the one hand, to gain recognition from his academic peers by engaging in basis research on some frontier of knowledge which may have no immediate application,

and on the other hand he has to develop good case courses and engage in applied work aimed at understanding and resolution of concrete managerial problems. It is often forgotten that developing a good case course may involve years of hard work, study and concentrated attention. Neglect of case collection work is further strengthened if the faculty perceive that the promotion process in the school puts a premium on project research and publication.

What should be the role of academic administrators in reconciling the teacher's personal objectives with the institution's requirements? This can best be achieved by allowing him to pursue a mix of research and consulting work which satisfies his needs for creativity and publication while he is constantly learning from experience in the field. The school authorities should indeed stimulate and guide the faculty's consulting activities and use them as instruments of faculty development. Often there are forces at work which tend to concentrate consulting activity in a select group of senior faculty members, but the authorities ought to pursue a policy of associating the younger faculty members with consulting activities to give them adequate opportunities to obtain this useful kind of experience. Such assignments not only satisfy their ego and status needs in the social world of the school but also give them insights into managerial decision making and contacts with executives which constitute an important asset in research and teaching activities.

Finally, administrative support is necessary in mobilizing institutional finance for supporting vigorous case and project research work. The case method is an expensive method of teaching. The recorded costs of case collection are always less than the properly allocable costs, since the costs of some cases are generally charged to consulting or project research activities.

Case Development Work in a Developing Society - Special Problems

Case research work in a developing society presents a special set of problems. A good number of business firms are family owned and controlled. In such firms, decision making processes are neither explicit nor formalized. This makes it difficult to ascertain and retrieve the data actually used or considered in the decisional situation; and since the decisional process is not documented it is not reported in the internal records of the organization. In most family firms, vital decisions are made on an ad hoc basis with little formal planning or explicit strategy discussion and policy formulation, which limits the scope for writing the comprehensive business policy type of cases. Most attempts to do this result in the case writer adding a lot of micro-level and environmental data which were not actually considered by the decision maker. This tends to make such cases akin to arm-chair cases. There are thus real problems of data collection in a developing

economy. At the macro level, data collection suffers on various counts. There is a large time lag in the publication of data, and it is also difficult to find industry-wide data in sufficient detail on a consistent basis over any reasonable length of time.

Yet another problem in a developing economy is the difficulty a case writer faces in successfully disguising his cases when only a few firms are operating in many industries. Especially in small countries it is much easier for those in business to identify any firm. Attempts to keep identity of the firm confidential by disguise of the industry or products or the scale of operations may virtually destroy the teaching-learning value of the case situation. There is also a greater unwillingness on the part of even the more enlightened businessmen to open up for case collection work and lay bare their problems for the scrutiny of the case writer. This is explained in part by the tendency toward detailed governmental regulation and control of business. There is therefore an apprehension by businessmen that case studies might unintentionally invite government attention onto them, or lead to some unforeseen trouble or irritation from some quarter. Another important factor is the close ties between social and business life. This explains why some business firms are unwilling to subject the actions of those whom they hold in high regard to being dissected by a case writer. Further, quite a few businessmen in developing societies have had no formal management education or training. They have therefore developed a sort of defensiveness against the scrutiny of their actions by people from universities, and sometimes rationalize their responses to the questions of case writers so as to make themselves appear more "professional." To this extent case description will not reflect the reality of the business situation.

Despite all these hazards, it is most important that management schools in developing countries should build up their own sets of cases for use in training and developing business executives. The temptation is to fall back on books of cases already collected, matured and published in North America or Europe. But the conditions in these countries are so different that the trainee who has relied only on the experiences imparted through cases in Western countries will be poorly prepared to tackle the real-life situations and choices he will face in his own country. Some cases from foreign countries may be introduced to illustrate points - for example situations which might arise in a trainee's future firm with the progress of national development but which are hard to document from current local practice. But for the most part reliance should be placed on the active, continuous collection of experience in cases from the national environment.

[Extracted from a paper presented to a conference of Asian Business Schools in Jakarta, Indonesia, November 29 - December 1, 1973.]

SOLAR ENERGY

SOLAR COOKER IN INDIA, WHICH CONCENTRATES SUN'S RAYS TO HEAT DISH IN CENTER. (PHOTO: UNITED NATIONS)

Solar Energy for Rural Development

U. S. National Academy
of Sciences

[The current and potential value of solar energy technologies for uses in developing countries is examined, with emphasis on small scale applications suitable in rural areas. This extract covers energy from the direct uses of the sun's rays and from indirect solar energy sources such as wind and water power, but excludes the fossil fuels (oil, coal, gas) and the energy derived from plants and trees; energy storage is discussed. The most promising current uses involve electric power from wind and water, and solar heating; research may in time reduce the costs of electricity from photovoltaic solar cells, with a larger but less certain potential.]

The relationship between energy and economic development is as crucial in the less-developed countries (LDCs) as in the industrialized nations. The process of economic growth is traceable in large part to the substitution of energy for muscle. Thus the prospects for growth in critical sectors of the less-developed economies are linked to the development and exploitation of energy resources available to them. The major contribution of energy to economic growth in the LDCs is now in areas that require conventional kinds of energy from fossil fuels, and this will probably continue to be the case for at least the next few decades. But fossil fuels are non-renewable resources, and supplies are inevitably finite. Whatever the world's reserves may be, they are becoming more costly and the demand for them is growing. One cannot reasonably expect those nations with exportable supplies of fossil fuels to share them with their neighbors-in-

need on any altruistic basis, and the costs are likely to go on increasing. For this reason it is of interest to see what alternative energy sources there may be.

The more promising energy technologies discussed in this report involve conversion of the energy in wind and water to electricity, and the use of solar energy for heating and perhaps cooling. To the extent that these technologies relate to demands that are matters of comfort--light, radio, television, space heating, cooling--they will not contribute significantly to improvement in national economic productivity. But there are applications of such technologies that can indeed contribute to overall economic growth. Improved communication, for instance stemming from the availability of modest amounts of electricity, can make possible the dissemination of vital information on agricultural problems, public health, nutrition, and family planning. Solar crop driers can play a significant role in improvement of crop storage, increasing both the quantity and quality of the usable crop at the end of the storage period. An array of small improvements, by relieving pressures on other energy sources that directly influence productivity, could have a long-term cumulative effect on a national economy and should not be discounted.

However, there is a generally high capital intensity that is characteristic of economically significant energy supplies from almost all sources. This constitutes the chief barrier to unconventional approaches to the use of energy technologies in the LDCs, where capital and the skills to employ it are scarce. Their governments are likely to find external funds most readily for major investments in the more conventional larger-scale energy projects that promise to contribute substantially to economic productivity.

Hydroelectric power, for example, simply will not greatly accelerate the industrialization of developing nations unless it is extremely cheap, and that means hydroelectric developments on a massive scale where topography and water supplies permit. Yet, relatively small projects using water flow as a direct source of energy or to generate electricity can be attractive in economic terms, even where there is no possibility of large-scale development. Small dams can be constructed by local labor with local materials, and they combine long life with minimal maintenance over a considerable range of scales of construction. Even so, it does not seem likely that significant changes in the use of hydropower can occur in the developing countries over the next 5 years, and the most that is predictable in the near-term future is a concerted effort to produce incremental gains in reliability and cost. Such gains are not trivial, but they do not suggest major opportunities to substitute local hydropower for imported fossil fuels.

Much the same comment can be made about the use of energy from wind. Wind is more readily available than falling water. For this

reason, the LDCs may well find considerable overall benefit in the use of wind power as a prime source of mechanical power, as well as in the generation of electricity, by harking back to small-unit technologies that proved so useful in rural Europe and America not too long ago. The ability to build structures of proven characteristics at relatively low capital and operating costs, using local materials and manpower, still carries the same rural appeal. Wind power does not, however, appear economically attractive for large-scale generation of electricity in the LDCs. This is true not only because of the storage problem, but also because such a program would involve both capital costs and more elaborate power transmission and integration technology than LDCs can afford at projected costs for such systems.

What may be said of wind and water power is applicable to the direct uses of solar energy. None of them is a developmental panacea; and their ability to displace fossil fuels is confined to specialized uses, primarily in rural areas. This is, at least, true of the short run prospects. In the longer run, given the possibility of advances in research and development - particularly in photovoltaic solar cells - and the potential increases in fossil fuel costs, there may be a larger role for nonconventional energy sources than is likely in the near term.

Direct Uses of the Sun's Rays

Solar energy represents a vast energy source that is most available in many areas where population density is often low and where conventional energy resources may be expensive. At present there are relatively few useful applications of solar devices, but there are many experimental and developmental solar energy utilization systems. These are being pursued in some of the industrialized countries, particularly the United States, the Soviet Union, Australia, Japan, France, Italy, Israel, India, and Canada. Experiments in these countries cover a broad range of potential uses of solar energy, including electric-power generation on a small scale, heating and cooling of buildings, water desalting by evaporation, cooking, food refrigeration, high-temperature materials processing, specialized solar drying, and certain combinations of uses.

Solar water heaters. In its modern form, the solar water heater is basically a flat-plate collector and an insulated storage tank. The collector is commonly a blackened metal plate with attached metal tubing and is usually provided with a glass cover and a layer of insulation beneath the plate. The collector tubing is connected by piping to a tank that stores hot water for use during non-sunny periods. When mounted on a roof or other suitable support, the collector absorbs solar radiation; by transfer of the resulting heat to water circulating through the tubing, hot water is supplied to the storage tank. In the most common designs, the storage tank is located above the

top of the collector. The elevated position of the tank results in natural convection: the hot water circulates up from the collector to the tank and no pump is required. A typical arrangement is illustrated in Figure 1.

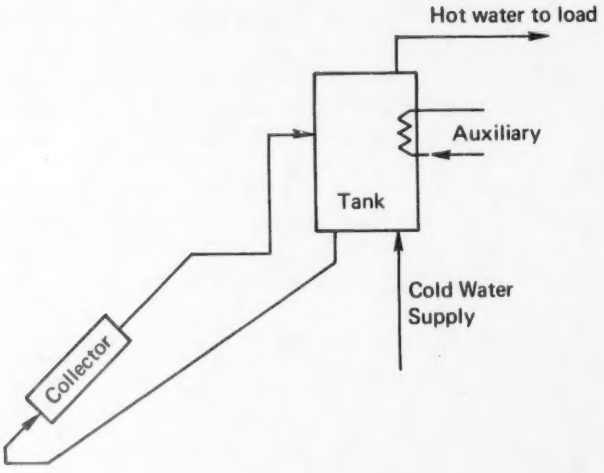


Figure 1. Schematic of a natural circulation solar water heater, with auxiliary energy added to the storage tank. [Courtesy John Wiley & Sons, Inc.]

Several countries have used solar water heaters for many years, most extensively in the United States before 1940. After 1950, water heater designs were greatly improved in Israel, Australia, and Japan. The general type described above was improved by incorporating better thermal contact between the black metal plate and the tubing through which water circulates, as well as by the development of black surfaces that provided greater net energy recovery from the sun. At present, about 20 percent of the households in Israel have solar water heaters. In Australia, solar water heaters were further improved in the 1950s and early 1960s, and several manufacturers went into production. They now have an established industry there and produce about 1.5 million units per year; in some districts of northern Australia, domestic water is heated almost exclusively by solar energy. In Australian practice, the absorbers (collectors) for household-scale use typically measure 8.6-17.2 ft^2 (0.8-1.6 m^2), with an 80-gal (300-l) water storage tank, optionally fitted with a thermostatically controlled 1-kW electric booster, producing about 50 gal (180 l) of hot water on a good day. In Japan, hundreds of thousands of solar water heaters have been manu-

factured and sold, many of a design that combines the collector and storage functions to produce hot water for use at the day's end.

The cost of solar water heaters varies considerably with the quality of construction, but in general the better metal/glass collector units with insulated storage tanks involve a price for the collector of about \$10-12 per ft^2 (\$100 per m^2) in the United States. For a typical, family-sized installation of 30 ft^2 ($3m^2$) and 50-gal (200-l) storage, a total installed cost of about \$300 can be assumed. The type of solar water heater in common use in Japan, providing hot water only in the latter part of the day and combining collector and storage, commands a price of \$100-\$150. In its simplest form, the solar water heater is free of moving parts and requires a minimum of maintenance. It is essentially a trouble-free plumbing system with an expected life of 10 years or more; maintenance depends largely on the rate of corrosion or mineral deposits caused by materials dissolved in the water.

Solar space heating. Although residential heating is not a primary problem in tropical developing countries, comfort heating in other areas would certainly improve living conditions. The technology of solar heating where water is the medium for transfer of heat is essentially an extension of the technology employed in solar water heating, except that heat has to be recovered from the tank through a hot water pump. Collectors and storage units much larger than those employed in solar water heaters are necessary to provide a substantial

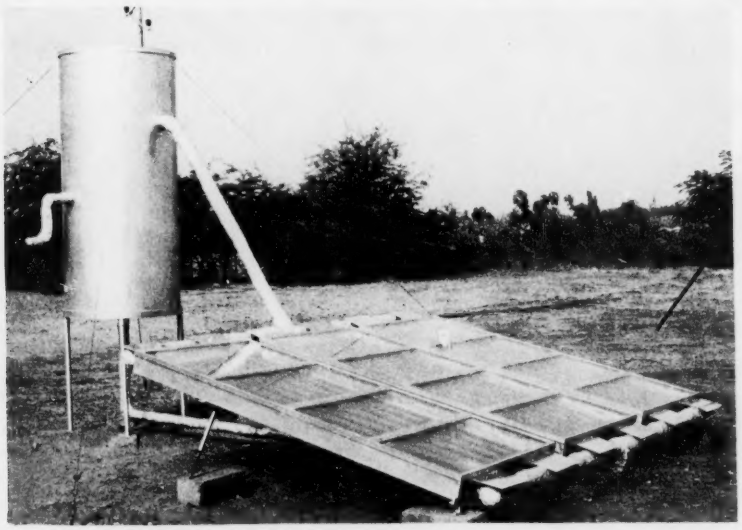


Figure 2. Solar water heater, Niamey, Niger.

portion of the heat requirement in a typical residence in a sunny climate. Systems employing air as the heat-transfer medium between collector and a storage bin containing small rocks (Figure 3) have also been used successfully. Solar heat is stored as heat in the rocks, and is recovered when needed by passage of air over the rocks and thence to the rooms.

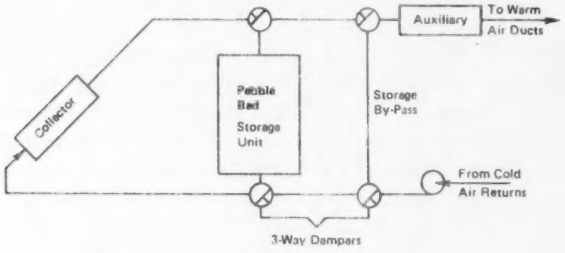


Figure 3. Schematic of basic hot air system. [Courtesy John Wiley & Sons, Inc.]

Several dozen experimental solar houses have been built and operated with the heating system comprising the collector, a heat-storage unit, an auxiliary heater, and appropriate heat-distribution-and-control systems. There has been much diversity in concept and design. Extensive economic studies have also been made that are applicable to industrial economies and these indicate that solar heating should be able to provide energy at costs competitive with other heating methods in many areas. A feasibility study of solar heating in Iran, for instance, indicates that it may be economically practical in that country. The main deterrent to widespread use of solar heating has been the cost of installing the system as compared with the value of the fuel saved by use of the solar facilities. In the industrialized countries, solar heating could not compete with conventional methods of heating with fuels such as petroleum, natural gas, and liquified petroleum gases. Only electricity has been sufficiently costly for solar energy to be competitive. During the past two years, however, the price of oil and gas has climbed so rapidly that it now appears that solar heating of buildings will become competitive with these fuels in the near future.

The primary reason solar water heaters have been competitive when solar space heaters have not is the difference in load factor on the two systems. The solar water heater is used all year, whenever solar energy is available, whereas the space-heating system is used only during the winter months. The net useful output of the solar water heater, therefore, is 2-3 times greater for the water heater than for the space heater, per unit of collector surface--that is, per unit of capital cost. Because of this, as well as the several-thousand-dollar cost of a complete solar space-heating system, there has been little application in industrialized countries and

even less in developing countries. But the recent severe increases in fuel prices have altered this situation in the United States, Japan, and elsewhere, and solar heating is now under rapid commercial development. Most studies indicate, however, that in cold climates it is not practical to provide 100 percent of the space heating requirement by solar energy, so that a solar heating system must also include a conventional heating system of adequate capacity to keep the structure habitable when the solar heat gives out.

Solar air conditioning. Conventional air conditioning involves the compression of a vapor, its cooling and condensation to a liquid, and subsequent vaporization by expansion into a region of lower pressure. Heat is withdrawn from the air which is to be cooled by drawing from it the heat needed for vaporization of the liquid; the cycle is repeated by a return of the vapor to a pressure at which it can be condensed, rejecting the heat of vaporization at a temperature higher than that of the cooled region. The heat of vaporization is rejected to either the outside air or a stream of water.

Solar air conditioning can be accomplished in the same manner by conversion of solar energy to the mechanical form needed to operate a compressor. The need for mechanical power and its relatively high cost from solar energy can be avoided by use of the absorption refrigeration cycle. In this process, the pressure of the refrigerant vapor is raised by heating instead of by mechanical compression; the vaporized refrigerant is recovered for recycling by absorption in a solution of the refrigerant and a salt. The low pressure of the expansion/vaporization region is maintained by the reduced vapor pressure of the refrigerant above the absorbent (solution), and the vapor is regenerated by allowing the solution of refrigerant and absorbent to flow into the generator where solar heat is applied. Other methods, such as air drying with desiccants regenerated by solar heat, are also possible. Technological feasibility seems assured, and economic feasibility appears promising.

Only two or three full-scale solar cooling experiments have so far been carried out (e.g., the Colorado State University House), and although they have been generally successful their results indicate comparatively high costs as against conventional compression cooling. Most of these development efforts have been associated with supply of a solar-heated fluid to an absorption refrigeration cycle of the type described, generally using the lithium bromide/water system as the absorbent-refrigerant mixture. Temperatures of operation are compatible with efficient flat-plate solar collectors, so a commercial air conditioner can be adapted to be combined with a solar heat supply by substituting the solar-heated fluid for the conventional heat source.

Solar refrigeration. Closely related to air conditioning, solar refrigeration is generally intended for food preservation or for storage of

biological and medical materials. There have been experiments in several countries including the United States, Sri Lanka, France, and the Soviet Union on solar-operated coolers, using absorption cooling cycles. Most of these are aimed at household-scale food coolers or small-scale ice manufacture. A single experiment in Mexico with a solar-operated, household-scale cooler was unsuccessful; although the machine was simple in design, it was too complicated to operate and therefore was not usable by the people for whom it was intended. There are a number of open questions regarding solar refrigeration. Its application has the attractive possibility of increased utilization of available foodstuffs if refrigeration could be successfully provided. But research and development are needed: today there is no practical solar refrigerator at any price.

Solar stills and desalination. The use of solar energy for desalting seawater and brackish well water has been demonstrated in several moderate-sized pilot plants in the United States, Greece, Australia, the Soviet Union, and several other countries. This century-old process--the basin still--has been modified and adapted to modern materials. It consists of a shallow pool of brine from which a slow evaporation of water condensing on the underside of the cooler glass covers runs to troughs at the lower edges and to storage. Excess brine that has not evaporated is run to waste as salt water is supplied to the basin. The idea was first applied in 1892 at Las Salinas, Chile, in a plant supplying drinking water for animals working in nitrate mining and transport. The Las Salinas plant reportedly operated for 30 years. Modern developments in solar distillation have been directed to the use of materials and designs for economical and durable construction, to reduce product-water cost. Solar distillation is now used on a small commercial scale to supply small towns and motels in isolated areas in Australia and small communities in the Mediterranean and the Caribbean areas.

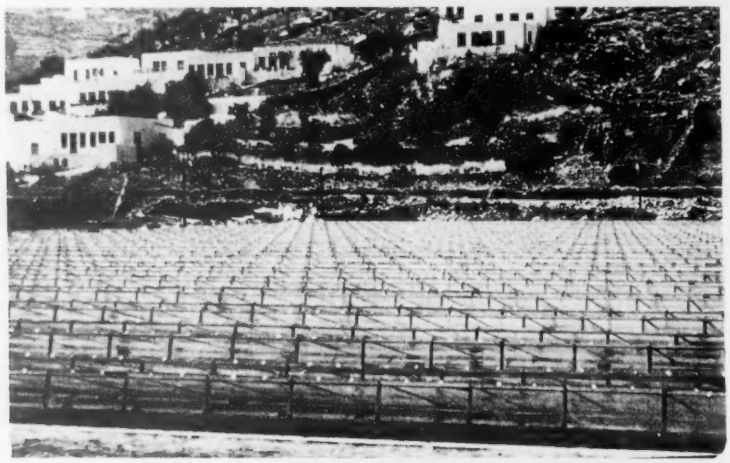


Figure 4. Solar still on the island of Patmos, Greece. (Constructed in 1967; total area 95,000 ft^2)

Solar distillation requires relatively large capital investment per unit of capacity but, in properly designed and constructed systems, a minimum of operating and maintenance costs. Reliable performance can be obtained with construction using familiar materials and local labor. Product-water costs depend primarily upon still productivity, service life, capital cost of the installation, and amortization and interest rates. Productivity of a solar still is dependent on the intensity and duration of the sunlight it receives. Experience shows that a still will yield about 25 gal/ft^2 (10,000 l/m^2) annually, with some variations dependent on climate and design. A typical lifetime for a still constructed of concrete, glass, and other durable materials is 20 years or more; other still designs involve less durable materials that must be renewed periodically.

The lack of more general use of solar stills is almost entirely the consequence of the high capital investment required and the resulting high cost of water produced. In recent years, durable solar stills have been built for a unit cost of \$1.50-\$3/ft^2 (\$16-\$32/m^2). If a durable solar still can be constructed for \$1/ft^2 (\$10.75/m^2), including materials and labor, typical yields would produce water at a cost of about \$3-\$4 per 1,000 gal (80¢-\$1.05 per 1,000 l). These figures may be compared with costs of desalted water from large fuel-fired evaporation plants in the vicinity of \$1-\$1.50 per 1,000 gal (25¢ per 1,000 l). There seems to be little prospect, therefore, that large solar distillers will be competitive with large desalting plants supplied with conventional energy sources unless fuel prices escalate greatly. However, in situations where a community or an industry requires small quantities of water--say, less than 50,000 gal (200,000 l) per day--the solar still may be more economical than the conventional desalting plant. The latter, operating at this low rate rather than at millions of gallons per day, requires a heavy investment per unit of output, with the result that the cost of water produced from it can be several dollars per 1,000 gal. Since the cost of the solar desalting plant appears to be competitive in small installations, there is the opportunity to use such plants: a) in small communities where potable water is unobtainable except at very high cost; b) in certain industrial and commercial applications where materials must be processed in a region where all available water is brackish; or c) for watering of livestock in areas where grazing is possible if water is supplied. It is for these moderate-volume requirements that solar stills have been built.

Solar crop-drying. Of all the direct uses of solar energy, sun drying of crops is perhaps the most ancient and widespread. The customary technique involves spreading the material to be dried in a thin layer on the ground to expose it to sun and wind. Copra, grain, hay, and fruits and vegetables are still dried in this manner in many parts of the world, including the industrialized countries. In recent years innovations have been adopted, particularly for fruit drying, in which fruit is placed in carefully designed racks to provide controlled exposure to solar radia-

tion and wind and to improve material handling. Improved process control and product quality have resulted. The term "solar drying" also has come to mean the process whereby agricultural materials are dried not by direct exposure to the sun--along with wind, rain, insects, vermin, and birds--but by means of solar-heated air in more protected surroundings. This process is of special interest in the case of the soft fruits; these are particularly vulnerable to attack by insects, as the sugar concentration increases during drying.

For dried fruits and vegetables, sun drying is the cheapest and simplest way to dry crops in regions having abundant sunshine and where the post-harvest season is characterized by low relative humidity and little or no rainfall. In the case of green lumber--where direct exposure to the sun tends to produce curling and warping in many woods--and in the humid tropics, kiln-drying can be accomplished with solar-heated air (the cost of this process is not yet well established). To remain stable in storage, agricultural crops should be dried to a moisture content of 12-15 percent by weight. The relative humidity of the air that will be in equilibrium with crops of that moisture level varies from crop to crop and ranges about 48-60 percent for fruits, grain, and hay. Marked decreases in relative humidity (RH) can be achieved with rather minimal increases in air temperature, and the temperature change needed to produce any desired change in RH can be ascertained from standard psychrometric charts. Adequate drying of crops can therefore be achieved in humid climates by raising the temperature of the air circulating among the items to be dried.

Although there is no significant commercial manufacture of solar crop dryers, experimentation over the past 20 years has produced a number of designs which are now in use. These range from the use of solar-heated air in more or less conventional air dryers to a combination of direct drying and air drying by placing the materials to be dried in flat-plate collector-dryers. Among the former are various designs developed in the United States, Turkey, Canada, Brazil, and Australia. Combination collector-dryers have been designed and used successfully in India and Trinidad. Development of solar drying can conceivably benefit from further development of collector-dryer combinations and flat-plate air heaters and energy-storage systems to supply hot air to dryers. Research in the design and control of these processes, for particular crops or other materials to be dried, could lead to other practical applications that could result in improved utilization of food supplies in developing countries.

Solar heat for power generation. Solar energy for power generation, either in the form of electricity or mechanical work, has been the subject of extensive research in the Soviet Union, United States, France, Italy, and Israel. (This is in addition to the photovoltaic approach discussed

below.) Efforts to generate power by use of heat engines have been the most numerous. All of these efforts have been more or less dependent on means of collecting and/or concentrating incident solar energy. A large assortment of solar collectors has been operated in numerous experimental assemblies to produce steam or other vapor, which then has been employed in engines of various types to generate electricity or mechanical power. The largest such unit was a plant built in Egypt in 1913, which developed about 50hp (37kW).

Most of the work has been directed toward the use of reflecting surfaces to concentrate the solar energy onto a small receiver/broiler, which permits the development of much higher temperatures than is possible with a flat-plate collector. High-pressure steam for electric-power generation or, with precise equipment, extremely high-temperature heat for chemical and metallurgical processing can thus be produced. Concentrators in the form of paraboloids (dishes), parabolic cylinders (troughs), and other shapes have been investigated. A design first studied in the Soviet Union and now being investigated in the United States, involves a large array of flat mirrors mounted on the ground and continually oriented to reflect the sun onto a high-pressure steam boiler. The boiler is located at the top of a high tower having a turbogenerator at its base.

Research and development specifically aimed at solar power generation in the less industrialized regions has been carried on in the Soviet Union, Africa, and, to a limited extent, in Israel. Notable among these efforts are several small solar pumping units of French manufacture in West Africa, based on a design by Girardier, and a similar installation in Mexico. Several installations of 1- to 3-kW capacity are in service. Present overall efficiencies of less than 1 percent could be substantially increased by design improvements. Although costs of power produced by this system are high, comparison with diesel units does not show a large difference when diesel engine life is assumed to be shortened by the lack of maintenance and repair personnel customary in remote areas. But in most situations the costs of solar power units are a major deterrent to their use; economic application would require major design and material savings, or usage in situations where the only alternatives are high-priced and short-lived small generators requiring costly fuel.

Electricity from Sunlight: Photovoltaic Devices

The direct conversion of sunlight into electricity is perhaps the neatest and most attractive of all schemes for the exploitation of solar energy. It is also, unfortunately, among the farthest from

Figure 5. Solar pumping station in Africa. (Flat-plate collector, organic-fluid Rankine engine; one of several built in the early 1970s) [Girardier, Ref. 55]

feasibility for widespread application in the developing nations at present. Direct photovoltaic conversion can be achieved with basically simple devices that involve no moving parts, no additional sources of energy, and little if any maintenance. These photovoltaic devices, which have become known as solar cells, are based on the properties of certain crystalline solids that enable these materials to supply an electric current capable of performing useful work when the material is exposed to sunlight. Although the devices are indeed basically simple, consisting of a wafer of crystalline material to which two metal contacts are fastened, their fabrication requires very sophisticated technological capabilities.

Solar cells, usually in the form of thin films or wafers, usually of silicon, are semi-conductor devices that convert from 3 percent to somewhat under 30 percent of incident solar energy into DC electricity, with efficiencies depending on illumination-spectrum intensity, solar-cell design and materials, and temperature. A solar cell behaves very much like a low-voltage (0.5 volt) battery whose charge is continuously replenished at a rate proportional to incident illumination. Connection of such cells into series-parallel configurations permits the design of solar "panels" with high currents, and voltages as high as several kilovolts. Combined with energy-storage and power-conditioning equipment, these

cells can be used as an integral part of a complete solar electric conversion system. Following their invention as practical devices in 1955, they have been used primarily for providing electrical power to spacecraft, though there have been some specialized terrestrial applications.

The extraordinary simplicity of a solar photovoltaic system (Figures 6 and 7) would make it appear a highly desirable energy system for terrestrial purposes. The attractive attributes of photovoltaic arrays include the absence of moving parts, very slow degradation of properly sealed cells, possibility for modular systems at sizes from a few watts up to megawatts, and extreme simplicity of use. The exceedingly high costs of development and fabrication of spacecraft solar arrays, however, have discouraged any serious thought of widespread terrestrial use of such technology at the present time. A complete spacecraft solar-cell array costs anywhere from $500,000 per kilowatt (average), for the Sky-lab arrays of 10 kW, to several million dollars per average kilowatt for early Mariner spacecraft arrays.

There is now good evidence, however, that with appropriate technological developments and mass-production techniques the cost of such solar arrays can be lowered perhaps as early as the mid-1980s to the point where a complete system--solar conversion, storage, power conditioning and transmission/distribution--could compete on a life-cycle cost basis with other large-scale energy-system alternatives, and perhaps be useful also in small-scale applications in remote rural areas. Substantial programs for the development of commercially interesting photovoltaic systems in the United States, West Germany,

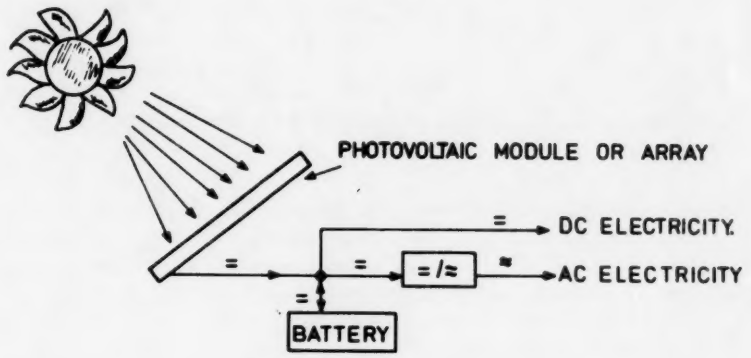


Figure 6. Simplified photovoltaic system.

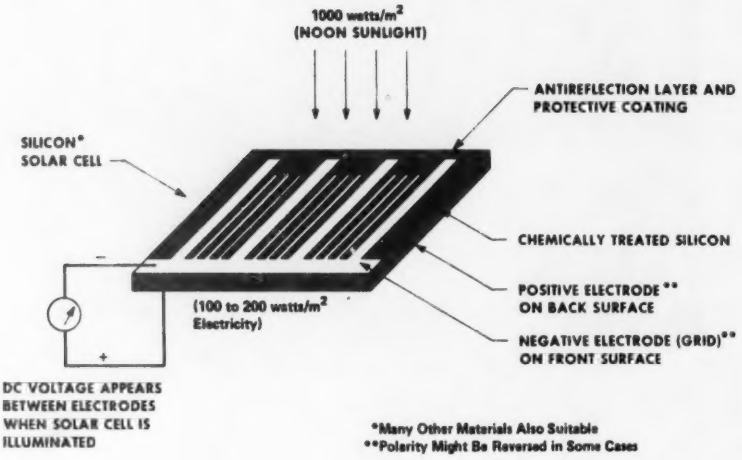


Figure 7. Direct conversion of sunlight into electricity - simplified representation of solar-cell operation.

Japan, and elsewhere have recently been initiated and, coupled with important developments in the past few years, now provide some concrete basis for such a prognosis. Important recent events include the development of continuous production of ribbon silicon suitable for solar cells, improvements in efficiency and stability of CdS (cadmium sulfide) solar cells, and the development of inexpensive, wide-aperture concentrators (Winston collector). In addition, a wide range of materials and systems are being explored in experimental testing.

In 1961, Kobayashi reported it was more economical, on a life-cycle cost basis, to provide remote power at levels up to 50W by a solar cell/storage battery combination costing $130/peak watt than to run a power line 1 km. Today, Spectrolab, Inc. has sold over 100 systems for remote power for navigational and warning lights on offshore oil rigs in the United States. California, Nevada, and Oregon are purchasing photovoltaic power systems for remote radio repeater stations and other similar applications; sailboat owners are purchasing solar arrays to keep batteries charged during long voyages; and the French are providing solar television sets in Niger (see below) for educational purposes. Small solar-powered radios were marketed by Motorola in the early 1960s and, at the extreme end of the luxury market, a West German company has recently introduced a solar-power (trickle-charged battery) electronic cigarette lighter for several hundred dollars! The total world market for diverse commercial and spacecraft applications

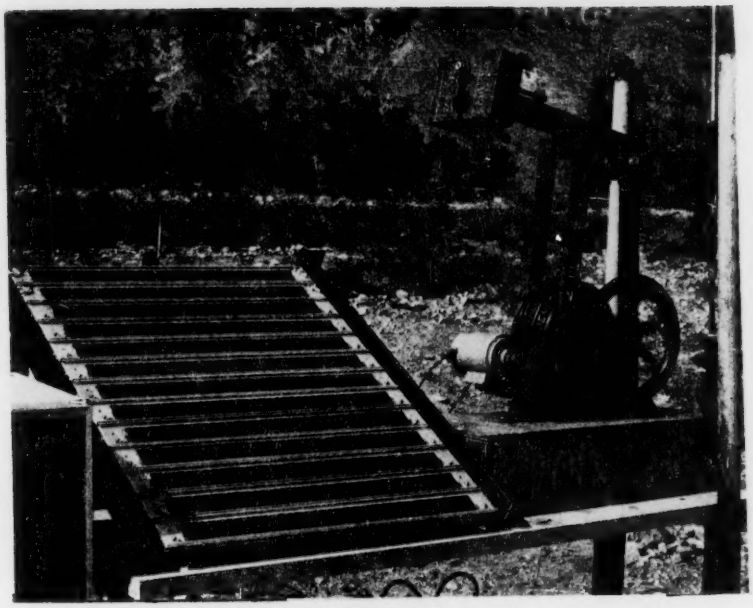


Figure 8. Water pump powered by silicon solar-cell array. Illustration shows one of four panels required to power the 1/4-horsepower motor that operates the pump. The array size is 36x 39 in. (91.4 x 99 cm) and it produces 4 amperes at 12 volts DC. [Courtesy Spectrolab, Inc.]

is roughly 100 kWe (peak) per year, and at present prices for photovoltaic arrays it is expected to grow to perhaps 3 times that within 3 years.

Of the various types of photovoltaic devices that have been manufactured, only silicon solar cells have become an established commercial product. Cells with other materials have been used in space applications by the United States and France, and by the Soviet Union. Nevertheless, silicon cells are the only devices that can be made reliably in quantity, remain stable with time, and whose operation is sufficiently well understood to enable properties to be predicted and electrical characteristics to be designed in. Commercial systems are available from manufacturers in the United States, Japan, West Germany, France, and England. Most of the devices and systems currently obtainable have been developed and used for specific applications where conventional energy sources are not available but where the need for modest amounts of power is critical in terms of commercial or military operations. Thus, they are too costly for applications in rural areas of

developing countries except where a specific and critical need might occur.

Some of the current applications are the following. In 1973, the Tidelands Signal Corporation of Houston, Texas, fabricated a complete aid-to-navigation, warning-light system, including silicon solar arrays and installed the system on an offshore oil platform on the Texas Gulf coast. The lighting system consists of one 2-mi fog signal and four 5-mi lamps. Energy consumption is about 25 amp-hr/day x 12 volts= 300 Whe/day. Previously, this lighting system was powered by 40 1.2 volt primary batteries; the total weight was 2,000 lb and these were replaced annually. The solar generator system incorporates 80 photovoltaic modules (1.22 x 1.52-m) array. The information available implies a retail cost of roughly $20/peak watt and indicates that at such prices for a terrestrial array (sealed, ready to install), such arrays begin to compete with primary and secondary batteries in markets traditionally served by this hardware.

Solar-powered educational television sets in Niger: this example is one of the very few documented applications of photovoltaics in a developing country. Television Scolaire du Niger (TVSN) was created in 1966 as an educational television system intended principally for primary schools located in regions without electricity. Reception is assured through the use of transistorized television receivers especially designed to operate with batteries in climates of extreme heat or cold. In order to develop a more economical source of energy, the technical services of TVSN in 1968 installed an experimental solar panel to power the television set at a school near Niamey. Six installations followed in 1972, and by 1973 some 800 students in 22 classes were receiving instruction via solar-powered television reception of broadcasts from the production center in Niamey. As a consequence of the encouraging results of this experiment, the Government of Niger decided on the progressive establishment of a network of solar-powered television sets, with plans to reach 80 percent of the population with education programs by 1985.

Photovoltaic arrays have no moving parts, and the basic physical mechanism that accounts for the photovoltaic property has a lifetime measured in thousands of years for silicon. Techniques have been developed to encapsulate silicon solar cells in a clear silicone material that provides excellent shock insulation and protection from environmental effects. The closer such encapsulation approaches true hermetic sealing, the closer the lifetime of the device will approach that of the base material. In the case of suitably designed solar-cell arrays, the level of maintenance required to provide very high reliability (on the order of one failure per 10 years of operation) is probably both low and inexpensive. It principally involves protection

of the transparent surfaces from extreme abrasion, and periodic cleaning of the surface and perhaps the electrical connections. Modules could conceivably be developed for which maintenance would consist of only occasional cleaning with soap and water. A number of photovoltaic systems have operated for close to a decade with no cleaning and with no observable degradation, despite such relatively dirty industrial atmospheres as the Cleveland Airport, for example.

As with any proposed investment, the cost of capital and fixed charges will be an important factor in determining the cost of energy from solar cells. In a photovoltaic system where the costs of the system operation depend primarily on the total capital investment in the delivered system, the interest rates applied to the loans will be particularly important, since the amortized cost of electricity will be almost linearly proportional to the interest rate. The actual cost of energy produced in a working environment will also depend on such factors as the efficiency of the cell as a function of temperature and of illumination intensity and wavelength, insolation patterns, and other local environmental factors. Since the realistic applications of such cells will be in integrated modules, the final costs must be determined in terms of the performance of these modules and not of the cells alone. The current price for individual silicon solar cells is approximately $10,000 per peak kWe ($40,000-$60,000 per average kWe), but the cost of a completed array (with or without storage batteries and power conditioning, which are relatively cheap) is $30,000-$70,000 per peak kWe ($120,000 and up for average power). Production of solar arrays or modules at prices more interesting in terms of rural use in developing countries would have to be for under $1,000 per average kWe.

Of the various techniques currently under development, only one seems likely soon to result in cost reductions, in the cell blanks and finished cells, of sufficient magnitude to bring total costs below $1,00/kWe within 5 years. This is a technique, currently undergoing commercial development by Mobil Tyco Solar Energy Corporation (Waltham, Massachusetts), for the production of continuous silicon ribbon of high enough purity and freedom from lattice imperfections to produce solar cells with conversion efficiencies in excess of 10 percent under standard conditions. It is difficult to predict whether such a price breakthrough will occur within 5 or 10 years. It seems likely that by 1985 such arrays will be available for about $500/kWe average; whether this could occur sooner depends on worldwide interest in and commercial demand for such systems.

Wind Energy

The source of wind is the atmospheric temperature differences generated by the sun, which, in turn, give rise to pressure differentials.

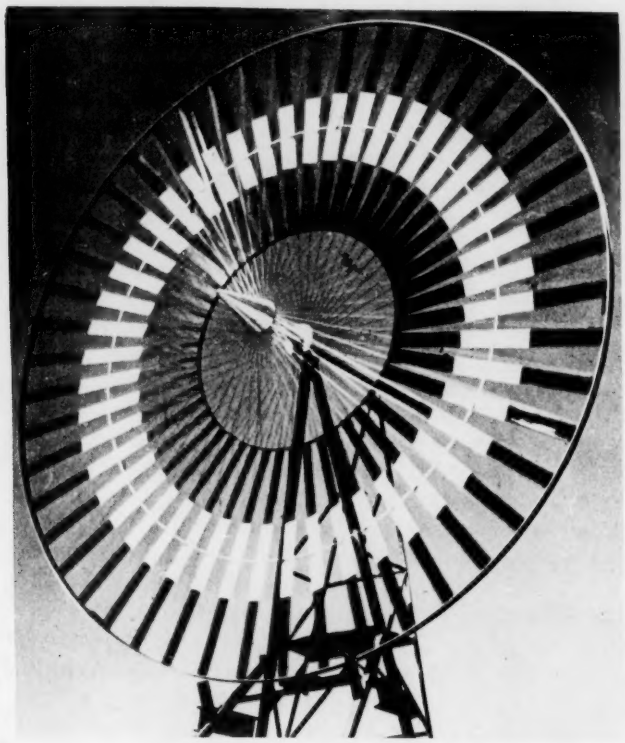
The wind is a mechanism for dissipating, as kinetic energy, the potential energy accumulated in those pressure differences. Wind energy has been used for thousands of years to propel boats and ships and to provide rotary windmill power to reduce the physical burdens of man. There is evidence that the ancient Egyptians used windmills as early as 3600 B. C. to pump water to irrigate their arid fields and to grind grain. The early Persians ground grain with a vertical-axis sailmill. Europeans imported the technology from the East and were probably the first to introduce the horizontal-axis mill around the 12th century. Almost all subsequent development has been with this latter type, primarily because of the low rotational speeds and greater efficiency of the horizontal-shaft mill.

The Asian experience with windmills also dates to ancient times. Today, in the People's Republic of China, windmills are currently used for irrigation on small holdings, using windmill-driven, scoop-bucket systems. The windmills are always constructed of locally available materials--bamboo and wood--and are generally built by the user. With minor modifications, the same device is used to grind beans and rice and for shelling crops, as well as for pumping. In Thailand, simple windmills constructed locally with wooden or bamboo poles and cloth sails have been used for many years to move water; more recently, a two-bladed, wooden-propeller type of windmill has been introduced. Here, the water is lifted by scoop-buckets attached to an endless belt, or by "water ladder."

In the United States, homemade windmills were a common sight, particularly in the semiarid Midwest, at the turn of the century. Among the windmills constructed by farmers for their own use, the following types were the most common: Jumbo windmill. The jumbo windmill was a kind of paddlewheel operated by the wind in much the same way that the overshot watersheel is driven by water. Its efficiency varied from 15 to 40 percent, depending on the design, and a typical design delivered up to 1 hp (750 W), depending on the wind speed. Merry-go-round windmill. Representing an attempt to increase the size and power capabilities of windmills constructed of wood, the merry-go-round windmill was a vertical-axis paddlewheel. It relied on a series of movable shutters surrounding the wheel that could be positioned to shield the blades from the wind on the "return" half of the wheel's rotation. When the shutters were closed, the mill resembled a closed circular cylinder. Battle-ax windmill. This mill, mounted on a wooden tower, consisted of four, six, eight, or more arms, each with a fan-like blade, fastened to a horizontal axis. When viewed edge-on while rotating, the assembly resembled a series of battle-axes slashing in opposite directions--hence the name. The construction was inexpensive and simple; battle-ax windmills are rugged mechanisms capable of performing useful work with a minimum of maintenance. Holland windmill. This is a version of the

familiar Dutch windmill that, in its traditional form, consisted of four or more slatted fans covered with cloth and fastened to a horizontal axis mounted in a rotatable structure that allowed the direction of the axis to change with the wind direction. In addition, the ubiquitous, commercially manufactured fan-mill was very popular for pumping water and generating electricity, and rapidly became a familiar sight throughout rural America. Thousands of these fan mills are still being used for pumping water on farms, primarily for watering livestock. Wind-powered electric generators were made and sold by the thousands before the advent of rural electric power.

Windmills as a source of mechanical power continue to be an appropriate technology for rural applications. For their construction and installation, they use locally available materials and labor and utilize local energy sources for a variety of tasks. When use of the windmill to generate electricity is contemplated, however, the technology required is somewhat more demanding for localized manufacturing. Not only is equipment required to generate, control, and distribute the electricity, but the details of matching the operating characteristics of the generator to the properties of the windmill require some engineering expertise. Windmill generating systems can be bought from firms in the U. S., France, Italy, Switzerland, West Germany, Australia, Argentina and South Africa.



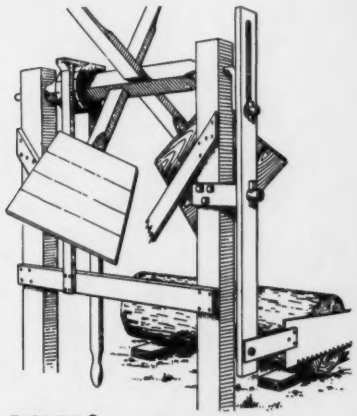


FIGURE 9. Battle-ax windmill driving cross-cut saw, built by A. G. Tingley, Verdon, Nebraska. [Source: Barbour, Ref. 5]

Figure 10. Bicycle-wheel turbine. [Reprinted from Popular Science with permission © 1977 Times Mirror Magazines, Inc.]

Figure 11. Elektro generator. [Courtesy Elektro GmbH]

Technology provides only part of the answer to the question of how reliably power can be extracted from the wind, and at what cost. In the first place, not all of the power in a wind stream can be extracted by a windmill. The power in a stream of moving air is proportional to the product of the cross-sectional area of that stream and the cube of its velocity, and it can be shown that the maximum fraction of that power that can be extracted by a windmill is 59.3 percent. As a practical matter, horizontal-axis wind devices achieve less than 70 percent of this theoretical maximum and vertical-axis machines are significantly less efficient.

Second, although the wind is a free and inexhaustible source of energy, it does not always blow, and when it does the velocity may be too low to allow the windmill to begin producing power; or it may be too high for the mechanical design that is practical for average wind speeds. In a review prepared for the Food and Agriculture Organization (FAO) Golding described the problem as follows: "At any specified point on the earth's surface the wind, at a given instant of time, can have a speed ranging from zero to

as much as 125 miles per hour (56 m/sec) or more. Even the windiest places have their calm spells while the least windy are occasionally subjected to storms which bring high winds. One cannot, therefore, rely absolutely on power from the wind at a given moment however windy the chosen site may be; on the other hand, one cannot safely reduce the mechanical strength of a windmill destined for a relatively calm area to any great degree."

Finally, the cost of a windmill, whether operating a pump, a generator, or used to grind grain or perform other mechanical tasks, must be evaluated in terms of the amount of useful power produced. This evaluation depends strongly on the average wind speed over the year and, of course, on the minimum wind speed at which the device starts producing useful power. Generally, the minimum speed is about 6 mph (2.4-3 m/sec). Manufacturers usually list outputs at the "rated" wind speed, which is generally about 15 mph (6.5-7 m/sec) although some large generators may be rated at higher speeds. The amount of useful power produced also depends on the ability of the user to use it when it is produced. In most parts of the world the wind blows at random times, and if the energy cannot be used when the wind provides it and cannot be stored against the time that it is actually needed--as electrical energy in storage batteries or as water pumped to an elevated reservoir, for example--the usefulness of even an elegant wind device is severely compromised. Therefore, one of the essential first steps is to obtain information on average wind speeds at the site contemplated, including data on the length of time during the year that the wind blows with a speed greater than a given minimum. Velocity-duration curves drawn from these data are useful in calculating the amount of power actually in the wind at a given site and, if necessary, the annual energy output.

Mechanically, windmills are far superior to fossil-fuel-powered engines in terms of reliability. Apart from their independence of fuel supply, they require minimum maintenance (usually an annual inspection and lubrication suffice) and seldom require repair. Some designs are self-regulating and even under the most adverse wind conditions require no care or attention. The cost of a wind system is closely linked to the type and height of the tower on which the machine is mounted. A large part of that cost is the cost of the tower, its design and the materials of construction. Because tower requirements--and hence permissible designs and materials--are so much a function of local circumstances, the cost of such a system cannot be comprehensively discussed here, but must be evaluated for each situation, based on requirements specified by the manufacturers of the various wind machines.

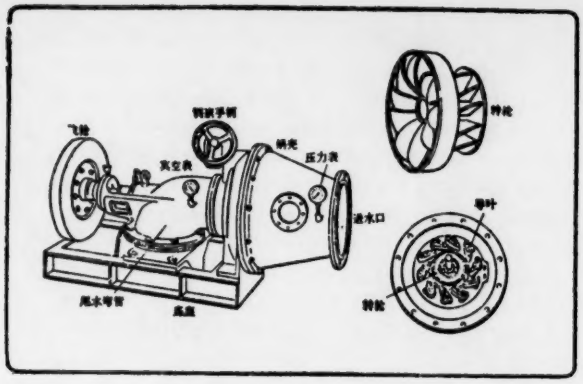
With the renewed interest in this ancient technology, ideas that have not been exploited, such as the vertical-axis Darrieus rotor, are being revived. In addition, many new ideas are being generated, along with prototypes of machines that represent attempts to put these ideas

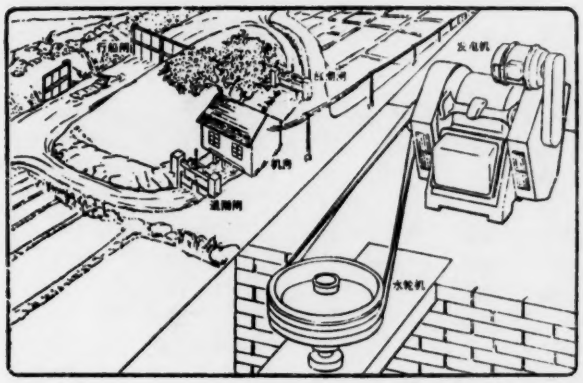
into practice. Although a new organization has recently been formed to coordinate some of these activities, it is primarily a trade organization concerned with manufacture in the United States. Because of the significant potential usefulness of this technology to rural areas in developing countries, a global research and development organization should be formed. With multilateral support, an international staff, and working through regional institutes, this organization would keep abreast of new theories and developments and test prototype machines developed anywhere in the world that show promise for use in developing countries. The staff of such an organization, supplemented by expert consultants, should be able to produce a coordinated and rational program of windpower exploitation based not only on assessment of new developments, but also on their own original research and development. Encouraging development of the ancient art of the wind machine could result in some revolutionary ideas for supplying the energy needs of rural areas.

Hydropower

Hydropower has as its energy source the potential energy of a supply of water at some superior elevation. This energy is converted within a turbine into mechanical energy that, in turn, is converted into electrical energy within a rotational electric generator, or into mechanical work. The power theoretically available from a waterpower site is equal to the weight of water flowing in a given time multiplied by the drop in elevation (the "head") of the water, considered as either horsepower or kilowatts. The actual power obtained is of course less than the theoretical power. The overall effect of the efficiencies of energy conversion into useful form (motion, electricity) is to reduce the theoretical power by a factor of 0.6-0.8. These energy-conversion processes and the means of carrying them out represent a mature technology with established paradigms, within which no major surprises have occurred for over 50 years.

Almost all current uses of hydropower are based on waterwheels or turbines. The waterwheel, turning with the flow of a river in which it is immersed in one of several ways, has been a familiar sight for years and needs no description. Energy efficiency of 20 up to 80 percent is obtainable, but on a limited scale. The water turbine differs from waterwheels in that there is a contrived steady flow of water through passages created by the turbine blades or buckets. The blades are so designed that water enters the passages smoothly and leaves with minimum velocity and energy, having transmitted most of its available kinetic energy to the rotor. This is the basic unit for generating hydroelectric power. [Note: although less space is devoted here to turbines than to two less familiar ways of using hydropower (see below), this is not because turbines are less important but because their potential is better understood.]





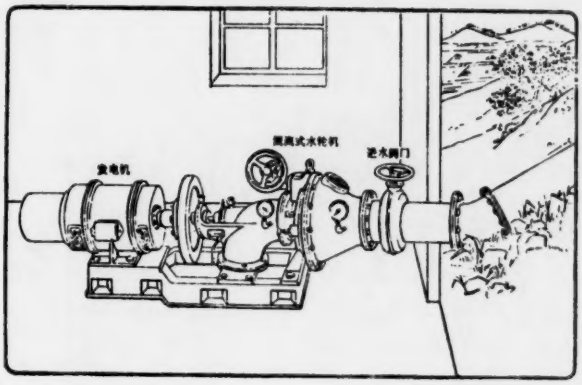


Figure 12. Francis turbine plant and details.

All turbines require that water be conveyed to them, under pressure, in large pipes or penstocks, from a source at some elevation above the turbine. The drop in elevation from the source to the turbine may be the result of natural conditions or may be artificially created by a dam. The dam not only serves to create the elevation difference (head), it also makes possible the storage of water to smooth out variations in stream flow. Ideally, the dam should be located at the point where a sustantial drop in the stream bed allows maximum power to be developed with minimum conveyance of water to the turbine. However, for reasons of economy and structural simplicity, the most desirable dam of minimum length and height may have to be located upstream of this point and a long penstock used to convey water to the turbine.

A brief survey of turbine manufacturers in the United States has shown that there is only one, The James Leffel & Co. of Springfield, Ohio, offering suitable "packaged" hydroelectric units off the shelf. The cost of these units ranges from $3,600 for the 0.5-kW unit to about $10,000 for the 10-kW size. A 10-kW unit developing 100-kWh/day, 350 days/year, with annual fixed and operating charges of 20 percent, would supply power at a unit cost of about 6¢kWh. This does not include the cost of the dam and penstock. The packaged Leffel units employ propeller-type turbines with fixed blades and are connected directly to the electric generator, doing away with the inconvenience, expense, and reduced efficiencies of using belts or gears. Leffel also offers its traditional line of Francis turbines (one of three basic types of design). The cost of a Francis turbine having a 17-in (43-cm) diameter runner and developing 20 hp (15 kW) at 294 rpm under a head of 10 ft (3m) would be $7,900. Its low speed would require a belt or gear connection to an electrical generator. The Soviet Union builds a fixed-propeller unit almost identical in size and form to the Leffel fixed-blade unit, called "Mikroges". Other hydroelectric units are available from England, Canada, West Germany and Hungary.

Published information and news reports indicate that a rather widespread and reliable technology of small-scale, low-head hydroelectric devices exists in the People's Republic of China. The available literature describes the use of small hydroelectric units, including Pelton, Francis, and Kaplan turbines. News reports indicate their growing popularity in rural areas and describe the construction and installation of thousands of units of less than 100-kW capacity, including one wooden turbine for a 20-kW hydroelectric plant. Information is also available on details of construction of wooden turbine and reinforced-concrete turbines for small-scale hydroelectric units. However, no details are available on either the specifications of such units or their commercial availability.

Small units of the types described may be expected to have a useful life of about 25 years with minimal maintenance. For uses in developing countries, the units now available should be examined with the aim of

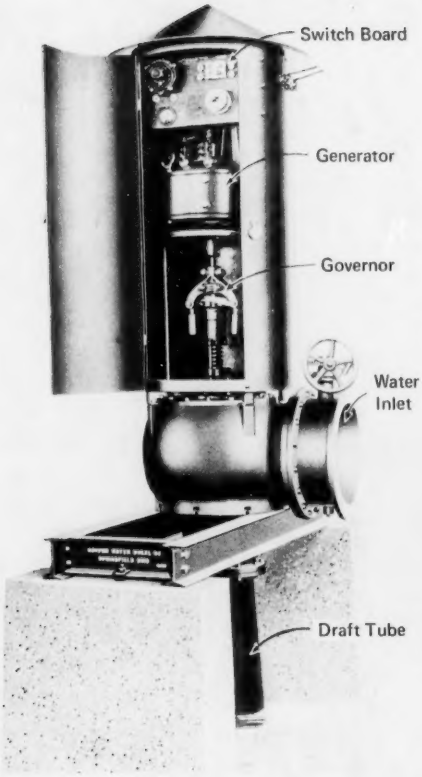


Figure 13. A 1-kw Leffel unit on a farm in Ohio. a) The 1-kW unit. b) Installation of the 1-kW unit. [Courtesy The James Leffel & Co.]

making them simpler and cheaper. It may be possible to eliminate the governor and much of the switchboard equipment. It has been reported that small wooden turbines are being made in the Soviet Union and China, although no firm information has been obtained from the Soviet Union. It may be worthwhile to pursue the idea of a low cost wooden turbine design.

Hydraulic rams. The hydraulic ram, the ingenious, automated water-pumping machine developed by Montgolfier in 1796, is largely forgotten today; at one time water was supplied to the fountains and lakes of the Taj Mahal by these devices. Present listings of manufacturers making "hydraulic rams" refer to manufacturers of hydraulic pistons and not Montgolfier's ingenious pump.

The hydraulic ram uses the kinetic energy of water flowing in a pipe to elevate part of this water to a height greater than that causing the flow, with an efficiency of about 60 percent. Figure 14 shows a hydraulic ram, and the principle of operation is illustrated in Figure 15. Water

flows through the supply pipe D, and through the opening of outside valve F. As the water velocity increases, the dynamic pressure on the underside of the check valve F increases until it overcomes the weight of the valve. Then F moves rapidly upward, closing the opening. The pressure of the moving water causes valve B to open and water is driven into the air-cushion chamber A, increasing the air pressure and discharging through the delivery pipe I. As the momentum of the water in the ram decreases, valve B drops down and closes and the water rebounds somewhat. This creates a sudden drop in pressure under valve F, causing it to drop down and open quickly and the cycle beings again. When valve B is closed, of course, the pressure in A is determined by the head of water in the storage tank and delivery line. Thus, the incremental additions of water to the storage system are the result of the momentary increases in air pressure in A at each cycle. The frequency with which the cycle is repeated is regulated by adjustment of the counterweight C.

A ram using a vertical fall of water of 12 ft (3.7 m), for example, will deliver 5 or 6 percent of the flow to an elevation of 125 ft (38 m); if the lift is to be only 25 ft (7.6 m), about 22 percent of the water flowing will be elevated. Though the hydraulic ram is customarily a device for pumping water, it has also been used to compress air for rock drills--during the building of the Mont Cenis Tunnel in Switzerland, for instance. The surge of water into the chamber at A can act as a piston to compress the air normally used as an air cushion when the device is used for pumping water. The suction part of the cycle becomes the air-intake cycle in this application.

Rams are completely automated, will operate 24 hours a day with minimum attention for months, and may be used to pump water for irrigation and water supply. In areas where iron pipe and pipe fittings are

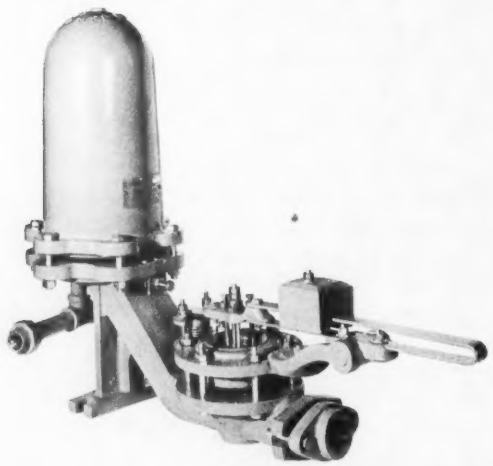


Figure 14. Hydraulic Ram (Courtesy Rife Hydraulic Engine Manufacturing Co.)

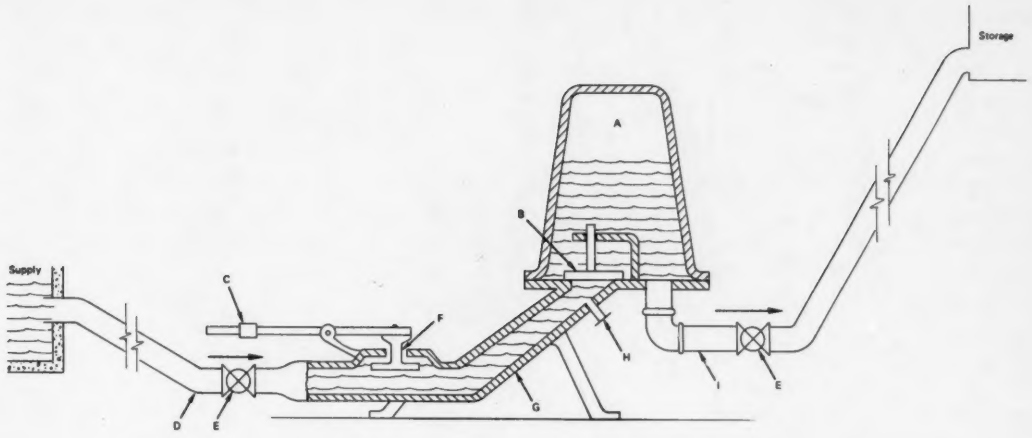


Figure 15. The hydraulic ram [Source: Village Technology Handbook, VITA, Mt. Ranier, Maryland, USA, 1970]

available, hydraulic rams could be constructed with local materials and utilizing local skills. Complete details for constructing these devices are available from VITA. (3706 Rhode Island Avenue, Mt. Ranier, Md. 20522, USA.) The hydraulic ram is so reliable and effective in its performance for the pumping of water that it does not require further development for this purpose. It would be worthwhile, however, to support research and development of the hydraulic ram as an air compressor. Such compressed air would be produced continuously and stored in tanks for use in reciprocating engines or turbines driving machines or electric generators.

Hydraulic air compressor. In medieval Europe this machine with no moving parts was known as the "trompe" and it supplied compressed air to aid combustion in Catalan iron furnaces. At the beginning of the 20th century it enjoyed a brief vogue in the United States as the "hydraulic air compressor." Basically, the hydraulic air compressor is the inversion of the air-lift pump. It is a simple device in which water at some elevation is allowed to flow into a vertical pipe through a circumferential Venturi (convergent-divergent) entrance. At the minimum areas of the Venturi section, openings are provided so that the water flowing past these openings will induce air to be sucked into them and become entrained in the water stream (Figure 16). If the water velocity is high enough, the entrained air will be carried to the bottom of the pipe and into a chamber where the air is trapped and compressed by the conversion of its kinetic energy to potential energy. It has been reported that an installation utilizing a fall of water of 71 ft

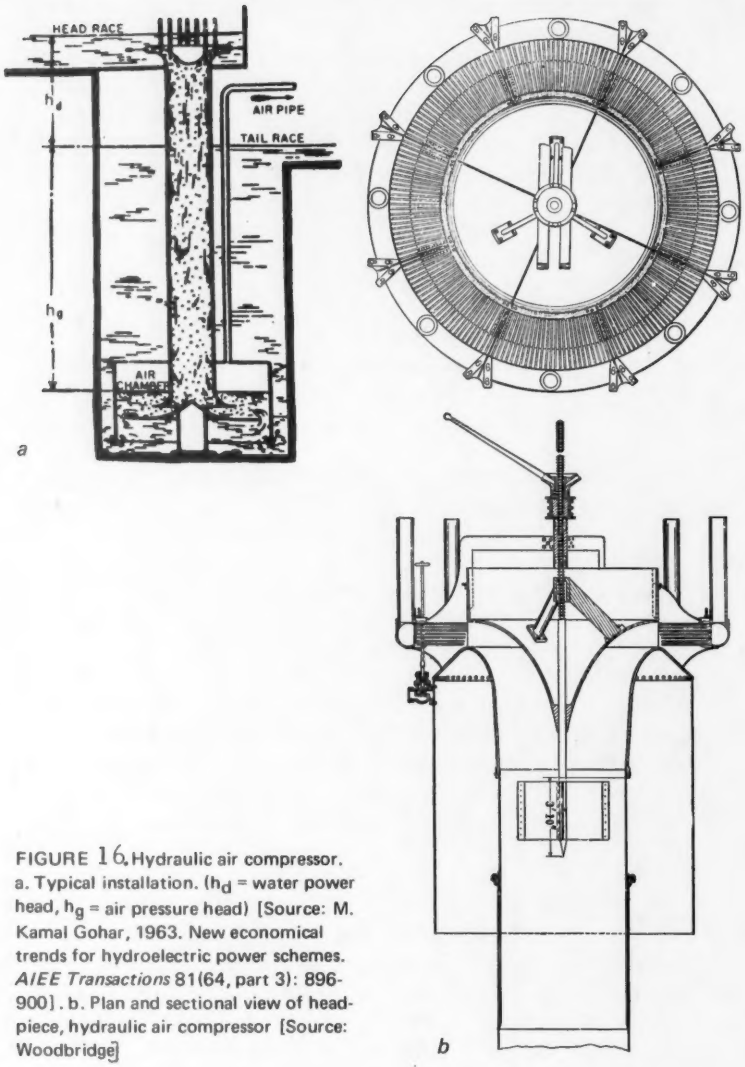


FIGURE 16. Hydraulic air compressor. a. Typical installation. (h_d = water power head, h_g = air pressure head) [Source: M. Kamal Gohar, 1963. New economical trends for hydroelectric power schemes. *AIEE Transactions* 81(64, part 3): 896-900]. b. Plan and sectional view of headpiece, hydraulic air compressor [Source: Woodbridge]

(21.6 m) with a pipe 5 ft (1.53 m) in diameter compressed enough air to a pressure of 117 lb per square in. (8.05 atmospheres) to develop about 1,000 hp (750 kW). The efficiency of this installation was reported as 82 percent.

This is a technology that could be available now. But because it seems to have been forgotten for almost 70 years, there are no known operating installations or available manufactured Venturi devices de-

signed for this application. The simplicity of this device and its high performance suggest that it should be resurrected for further study and possible use in hilly terrain where ample water is available. The ability of the device to operate continually day and night, with its simple storage of energy in the form of compressed air in tanks or caves, makes it an interesting and potentially fruitful problem to investigate. The compressed air could be piped to sites to drive reciprocating engines or turbines that, in turn, could power production machines or electric generators.

Energy Storage

The use of intermittent or variable sources of energy, such as solar and wind energy and some of the forms derived from moving water, often becomes practical only if some means of energy storage is possible. Specifically, we are concerned with storage methods feasible within the constraints under which rural communities in developing nations operate: there must be minimal requirements for capital investment, sophisticated equipment, or complicated maintenance. Conventional fuels are simply cases of sun-derived energy converted to, and stored in, chemical form. With oil, natural gas, and coal, nature has done the storage for us. We shall have to devise shorter processes to obtain the same results if we are to make the use of intermittent energy sources practical.

The basic energy-storage problem is to devise ways to take energy in whatever form available, convert it (if necessary) to forms best suited for storage, and then reconvert it, with minimal loss, to a useful form at the time it is needed. The principal physical possibilities include mechanical, chemical, and thermal storage.

Storage of energy in mechanical form. Mechanical energy may be stored in the form of potential energy by pumping water to a reservoir at a higher level; it can flow down to a lower level whenever the energy is required. This is conventionally called a pump-back system. The kinetic energy of the flowing water is usually converted to electrical energy, although it could, of course, be used directly as mechanical energy. Simple water wheels provide direct mechanical energy whenever stationary mechanical power can be used; when the energy must be moved from place to place, electric generators are probably the best possibility.

A difficulty of the pump-back storage system is that relatively large reservoirs are required. Generally, the best possibility in developing areas is to try to find a reasonably large basin for an upper reservoir located near an existing lake or river. The latter then becomes the lower reservoir. With current technology in pump-back systems, generally about two-thirds of the energy is available for reuse after

storage. The feasibility of such a system, however, usually depends on an energy market sufficient to justify the installation of the primary pumping system and its energy supply. Then the pumping from lower to upper reservoir can be accomplished economically during off-peak periods, making supplementary energy available during periods of peak demand. Wind-energy systems providing electricity and/or mechanical services during the day and pumping at night might be one example.

Still another method for storing mechanical energy is through compressed air. Two basic methods are of interest: direct compression, and isothermal hydraulic compression. Direct compression, to be practical, requires the availability of natural or man-made underground caverns that can be sealed and pressurized. Reuse of the stored energy requires the availability of low-pressure turbines or piston engines similar to the old-style steam engines. Generally, such systems provide a relatively low overall efficiency. About one-third of the initial energy can finally be reutilized. This figure can be improved considerably when compressed-air systems are combined with gas-turbine cycles or with refrigeration cycles, but the latter are probably not immediately applicable to our major interest in rural areas.

Of greater interest to small communities and rural areas in developing nations is isothermal hydraulic compression. In this process (which is at least 3,000 years old), a vertical tube is placed in front of a dam that is creating a head of water, typically 5-10 m (15-30 ft) or more. Water flowing into the inlet entraps air bubbles that are carried to the bottom with the water. The water then passes through the bottom of a sealed tank or cavern where the air bubbles rise. Ultimately, the air in the tank or cavern will be compressed to a pressure slightly less than that of the hydraulic head of the vertical (Venturi) tube. That compressed air can then be used in a simple turbine or other suitable expander to obtain usable mechanical energy. Such isothermal hydraulic compressors were used from ancient times until the latter part of the 19th century when they were gradually replaced by electrical, steam, or internal-combustion devices.

Storage of energy in chemical form. Although the input and output energy for a battery is electrical, the actual energy storage is in chemical form. The most widely known device is the conventional lead-acid battery; the technology is mature and the costs are fairly well known. The storage efficiency is about two-thirds, or roughly the same as for pump-back storage. The battery life is fairly long, perhaps 10 years or more when properly maintained, but the cost is high if one wishes to store enough energy for significant use. In some cases, however, it is the only thing available. In such circumstances, it may be used to operate a few lights, television sets, and similar low-demand devices, but it will be too expensive for light industrial or vehicular applications.

Electrolysis of water represents another technique for storing energy in chemical form. The stored product is hydrogen, which then can be used as a simple fuel. To minimize storage requirements, it must be stored at relatively high pressures; even so, the energy density is fairly low. Nevertheless, one of the major attractions of this approach is that the basic raw material is distilled water, and it is possible to develop simple devices to run on hydrogen directly. These include simple heaters and internal-combustion engines. The former could be used for space heat, grain drying, cooking, etc.; the latter could be adapted to small, rather short-range vehicles such as "mini" tractors and "mini" trucks. In a rural, small-village situation, these devices could be extremely useful and would not require imported fuel. Development of simple electrolysis systems, and simple heaters and engines using hydrogen as a fuel, should have high priority.

One interesting facet of electrolysis is that it can be performed with very high efficiency at very high pressures, provided the temperature is elevated to about 200°C. Efficiencies of 92-93 percent can be achieved at pressures of 150-250 atmospheres at these temperatures. These pressures can be created by the gas generated if the system is properly designed, and this would eliminate the need for compressor pumps. Generally, the elevated temperatures can be achieved by insulating the pressure vessels and using the internal losses to supply the necessary heat. Thus, the whole electrolysis system is essentially a static (no moving parts) system with the exception of manual valves. The input energy must be electricity which, for the time being, could be obtained from wind-generation systems (Figure 17).

Energy can also be stored chemically in the form of combustible hydrocarbons and alcohols synthesized from hydrogen and organic materials. Many such processes are under study throughout the world, but none is yet known to have short-term applicability to the rural community in a developing nation. (Anaerobic bacterial processes may be an important exception to this statement; this subject is covered in a separate report.)

Storage of energy in thermal form. Energy can obviously be stored as heat in appropriate materials, provided suitable thermal insulation surrounds the storage substance. Water and rocks, materials of high-heat capacity that are generally available, are commonly used as storage media. Variable sources of energy such as solar heaters or wind generators can then be used. The major difficulty is that the energy can be effectively reutilized only as heat; reconverting the heat energy to electrical or mechanical energy always involves significant losses because of fundamental thermodynamic limitations. Maximum reconversion efficiency to mechanical or electrical form would be only a few percent. Nevertheless, direct reuse as heat can be practical, and this is done in some places, as in solar heating.

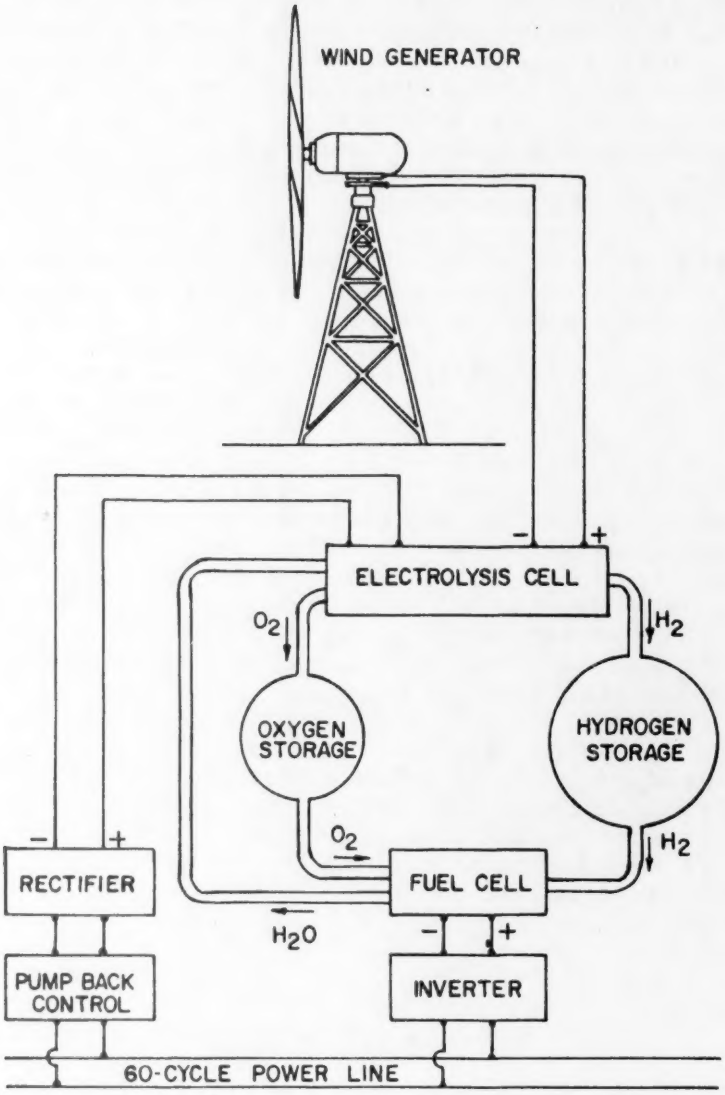


Figure 17. Wind as power source. [Source: Utilization of Resources: The Role of Energy in the Development of Human Settlements in Africa. United Nations Economic and Social Council, Document E/CN. 14/HUS/6. 17 April 1975.]

Research possibilities for energy storage. There is much current interest in the development of "super flywheels," which are proposed devices constructed from exotic materials of high tensile strength. Long-term development possibilities look rather good, but because the manufacture of the required sophisticated materials will call for high technological capability and large capital investments, the applicability of this technology to rural areas in developing nations is really a long way off.

Much research has been conducted on batteries other than the conventional lead-acid battery, and that research is continuing. It is primarily directed at reducing the weight per unit of energy stored so that electrically driven vehicles might become practical. The most promising work has been with batteries operating at rather high temperatures, or with batteries using expensive materials such as silver. As far as we know, there is no new battery on the horizon that shows more promise for rural areas than the conventional lead-acid cell. The use of hydrogen as a fuel will depend on results of further research on storage and transportation as well as on developments leading to simplification of the electrolysis process. However, there is little prospect that this process will become practical for use in rural areas of developing countries within 10 years or so. For similar reasons, current research and development on fuel cells should not be counted on to make these devices available in villages any time soon.

The only known techniques of storing electrical energy directly without changing form are in very high-intensity electric fields or very high magnetic fields. While some work is being done with these techniques, the technology requirements and costs are extremely high, and the possible energy densities achievable are, so far, very low. Unless some breakthrough occurs in techniques or materials not foreseen, these methods will probably not be useful for long-term storage in either industrialized or developing nations in the foreseeable future.

[Extracted from Energy for Rural Development, prepared by the Panel on Renewable Energy Resources of the Advisory Committee on Technology Innovation of the Board on Science and Technology for International Development, U. S. National Academy of Sciences. Washington, D. C., 1976.]

Power from the Sea

Mark Swann

[The use of temperature differences between the warm surface and cold depths of the ocean as a source of power is a novel idea, just beginning to be explored. The technology may be regarded as feasible; but the costs of power generation are very difficult to estimate.]

One of the most tantalizing potential energy sources in the world today is relatively unknown to the general public - it is sea thermal power, a method of producing energy by using heat engines to harness the small temperature variations between the sun-heated surface of the tropical seas and the cold deep water. Such thermal power is by far the ocean's greatest renewable energy source, being replenished daily by solar radiation. One team of researchers has estimated that this power source is capable of providing, on a continuous basis, 200 times the earth's total power needs in the year 2000.

It would be possible to operate sea thermal power plants at full output for 24 hours a day year-round in tropical areas because the surface of the tropical seas never falls below 78 degrees F. at any time. All other proposed systems for use of solar energy require some means of storing heat or electricity when the sun is not shining at night or behind clouds, and are generally dependent on variable weather.

How It Works

The heat engines in sea thermal plants transform heat energy into the mechanical work of spinning a

Mr. Swann is a free-lance journalist specializing in environmental subjects.

turbine. According to the second law of thermodynamics, heat can be transformed into work only while it flows from a hotter "heat source" to a colder "heat sink." In a steam turbine powered by oil or coal, fuel is burned to provide heat, and the natural outside environment is the heat sink. The burning fuel heats water in the boiler, producing steam which expands and is driven by the rush of heat to the heat sink. The turbine harnesses the rushing steam. Some of the steam condenses into water as it gives up energy in the turbine. Remaining steam is condensed in the heat sink, called the condenser (see Figure 1). This entire process is what is meant by harnessing the difference between two temperatures. The application of this principle to the ocean's stored heat was first suggested in 1881 by Jacques d'Arsonval. One of his students, Georges Claude, went on to build a small working sea thermal plant on the coast of Cuba in the late 1920s. [Note: Aside from another plant built off West Africa by the French in the 1950s, there have been no other plants put into operation so far.]

While steam is the working fluid in a steam turbine, Claude used warm sea water as the working fluid in his sea thermal plant, a method now referred to as the Claude process, or the open cycle method. The problem with the Claude process, however, is that the air pressure on

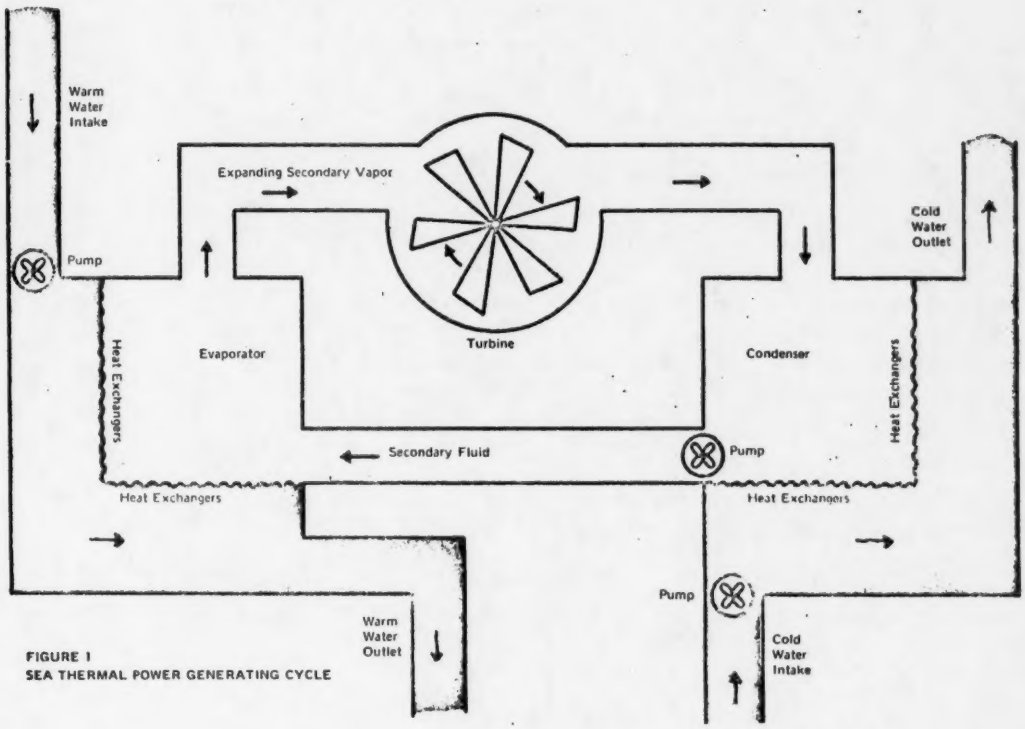


FIGURE 1
SEA THERMAL POWER GENERATING CYCLE

the warm water must be lowered to a point where vapor will form which can propel a turbine. Water vapor, however, has a low density which requires that the turbine have a proportionately large area of vanes. Such a turbine for a commercial plant would be inordinately large, expensive, and difficult to maintain. An open cycle turbine for a 100-megawatt sea thermal plant, for instance, would have to be more than 40 feet in diameter.

An alternative to warm water would be a type of working fluid which vaporizes (boils) at the upper reaches of the given temperature range, yielding a high-density vapor, and, of course, condenses in the lower end of the range (as in an ordinary refrigerator). Warm and cold sea water would then be used alternately to vaporize and condense the working fluid. Turbines for the working fluids - of which ammonia and propane are two possibilities - can be approximately one-tenth the size of an open cycle turbine using water.

The use of a working fluid other than vaporized sea water, however, presents its own problem: Heat exchangers must be built into the plant design. A heat exchanger is simply a surface - usually metal - which separates the working fluid from the heat source and the heat sink, permitting the heat to travel from the source (in this case, warm sea water) through the working fluid (a more volatile fluid) and into the heat sink (cold sea water). There are many technical difficulties associated with the design of efficient heat exchangers for sea thermal plants.

Location

The best location of the sea thermal resource is in the 1,700-mile-wide area around the equator between the Tropic of Capricorn and the Tropic of Cancer. Some of the most promising areas for sea thermal development are the South Atlantic Equatorial Current area, the Gulf of Panama, Micronesia, and the northwest coast of Australia south of Java. Other areas with usable temperature variations are the sea around Hawaii, most of the Caribbean, the Gulf Stream off the east coast of Florida, the Gulf of Mexico, the Arabian Sea, the Indian Ocean, the East Indies, and the Atlantic Ocean off the coast of West Africa.

One of water's most important properties in this application is that it forms relatively stable isothermal layers - layers determined by temperature and density - which can be tapped for sea thermal power without significant disturbance. In general, warm water flows away from the equatorial regions, while cold water from the polar regions flows under it toward the equator. In the Gulf Stream off the east coast of Florida, for example, warm sea water flows northward in a current more than 100 feet deep at a rate of 27 million tons per second, with cold water flowing southward just beneath it. As the cold water reaches equa-

torial regions it is heated, its density decreases, and it rises to the surface to begin its flow toward one of the poles. The reverse process takes place with warm water reaching the polar regions. This vast ocean circulation guarantees the renewability and reliability of sea thermal power's heat sink.

Cost Factors

While nuclear and fossil-fueled plants operate with artificially induced temperature differences of hundreds of degrees, sea thermal plants must operate on small, naturally occurring temperature differences of only 30 to 40 degrees F. Given a heat source and a heat sink, there is a maximum theoretical amount of useful work output. With a large temperature variation, the maximum theoretical amount is close to 90 percent; with a smaller variation, it is less than 10 percent and the actual amount of useful output is approximately half of the theoretical. Hence, a sea thermal plant will only yield about 2 to 4 percent efficiency in actual operation, while nuclear and fossil-fueled plants yield 30 to 40 percent. For many years this extremely low efficiency discouraged investigators of sea thermal prospects. If the fuel is free, however, the efficiency factor can change significantly. With the costs of all conventional fuels continuing to escalate since 1973, alternative energy sources have been more closely examined than ever before. In 1974 the U. S. Energy Research and Development Administration (ERDA) awarded large grants for parallel feasibility studies of sea thermal power to two aerospace companies, TRW, Inc., and Lockheed Missiles and Space Company, Inc. These studies resulted in cautious corroboration of the conclusions of earlier pioneering studies: Sea thermal power is technically feasible, and may in time become commercially promising.

The TRW feasibility report included an examination of the cost estimates of three different sea thermal research groups. These ranged from $1400 to $1700 per kilowatt. By comparison, estimated construction costs of nuclear plants planned for 1985 operation will range between $830 and $1,000 per kilowatt. Coal-fired plants, including devices to reduce emissions of sulfur dioxide and particulates, will cost about $750 per kilowatt to build. ERDA's position, based on the TRW and Lockheed studies, is that sea thermal power will be commercially attractive if the predicted capital costs could be cut from the estimated $1,400-to-$1,700 per kilowatt to about $1,000 per kilowatt. Clarence Zener, professor of engineering at Carnegie-Mellon University, believes that the cost of one of the most expensive items in a sea thermal plant, the heat exchangers, might be cut in half if specially designed surfaces to improve heat transfer were used - an improvement which would make possible the use of heat exchangers with a smaller surface area. Most researchers agree that the development

of low-temperature heat exchangers, a relatively new field, presents the greatest challenge in the field of sea thermal power.

Large Scale Units. Unlike conventional heat exchangers, sea thermal exchangers must handle enormous quantities of water - about 13,000,000 gallons per minute in a 100-megawatt plant. This is a large plant, to be sure, but the use of sea thermal power can only be economic on a large scale. The area of the exchangers must be correspondingly large, running into millions of square feet. Since the available temperature variation is small, the efficiency of heat transfer must be high. While the heat exchangers in sea thermal plants are not required to withstand the high temperatures characteristic of nuclear and fossil-fueled plants, they must be able to resist corrosion by sea water. Fouling by marine organisms (slime and barnacles) could also be a very serious problem. Mechanical or chemical cleaning may be too expensive, as well as possibly harmful to marine life in the surrounding water. The choice of materials and design for heat exchangers must take all of these problems into consideration.

Most of the construction of sea thermal plants will be done in shipyards. Tugboats will move the plants to their sites out in the ocean. The job of stationing a sea thermal plant on site involves problems of ocean engineering. The greatest challenge here is probably presented by the cold-water pipe, which must have a very large diameter (at least 40 feet) in order to decrease expensive pumping requirements. The pipe must be from 1,000 feet to 4,000 feet in length, depending on the site, in order to obtain the coldest water possible. With the small temperature range involved, each degree of temperature difference is crucial; questions of economy, such as whether it is worthwhile to lengthen the pipe to obtain water which is one degree colder, will have to be decided on the basis of further research and experience.

Several types of cold-water pipe have been proposed: concrete pipe resting on the ocean floor, telescoped concrete sections with voids for buoyance, welded reinforced aluminum, steel pipe with inner walls of smaller-diameter pipe, and reinforced synthetic pipes. Research is now being done to determine the static and dynamic loads on these various pipes. Fiber-reinforced plastic, or nylon coated with neoprene and stiffened with steel rods, appear to be promising materials for the cold-water pipe. It is not clear at this point whether the technology has advanced far enough to enable such a pipe to be constructed economically. The size and construction of the plant's hull are also significant factors in determining cost and siting. TRW's and Lockheed's baseline concepts call for very large cylindrical and spar hulls of reinforced concrete which will house the turbines, the pumps, and the heat exchangers.

The most formidable ocean condition is the "sea-air interface," where waves, winds, and storms can do much damage. The best strategy is simply to submerge a large portion of the plant to depths where the water

is free of wave action. The resulting stability will be much greater than, for example, that of off-shore oil rigs. Maintenance, of course, is made more difficult, but most of the plant should be relatively maintenance-free.

Sea Thermal Products

Neither the TRW nor the Lockheed investigators were asked to study the question of energy delivery to shore. Yet energy delivery is obviously of great significance for sea thermal power because the best plant sites, generally speaking, lie far from the biggest users of electricity.

Most investigators have come to realize that forms of energy other than electricity will probably have to be produced if the use of sea thermal power is ever to become widespread. One such use, first proposed by William E. Heronemus of the University of Massachusetts, is the production of hydrogen at the plants by electrolysis. Many experts consider hydrogen theoretically the ideal synthetic fuel: It can be mixed with natural gas; it can power fuel cells; it can be burned in power plants; and, unlike electricity, it can be stored cheaply. Other investigators, especially G. L. Dugger at the Applied Physics Laboratory at Johns Hopkins University, have proposed the production of ammonia, an energy-intensive product usually manufactured from natural gas. Dugger would combine nitrogen removed from the air with hydrogen produced by electrolysis to make ammonia.

The most ambitious proposal so far has been made by J. Hilbert and James H. Anderson, founders of Sea Solar Power Inc., who are the modern pioneers of this technology. They envisage an industrial complex floating at sea. Hydrogen, methanol, and ammonia could be produced using onsite power. Fresh water, marine food, carbon dioxide, oxygen, and nitrogen could also be produced with relatively little power consumption.

The Andersons propose to deaerate the warm sea water before sending it through the heat exchangers, in order to control fouling of the exchangers by aerobic organisms. The components of the removed air - mainly oxygen, carbon dioxide, and nitrogen, which are present in higher concentrations in sea water than in the air above - could then be separated by refrigeration techniques. The yearly income from carbon dioxide is estimated at $32 million; from nitrogen, $6.5 million; and from oxygen, $5.5 million.

The electricity itself would be worth $17 million at 25 mills per kilowatt-hour. If the electricity is used for electrolysis, the resulting hydrogen, at $1,900 per ton, is worth $33 million. Additional oxygen worth $6.5 million would also be produced. The synthetic fuel, methanol,

can be produced by combining hydrogen from electrolysis with carbon dioxide, but at current prices such production is not profitable. Ammonia, which can be produced by combining hydrogen and nitrogen, would cost $170 per ton to produce and, again, may not be profitable at this time.

Fresh water could be produced by vaporizing some of the used warm sea water and then condensing it with used cold water. In a 100-megawatt plant, 2% of the water would run to about 150 million gallons per day. At 20 cents per one thousand gallons, the fresh water could earn $11 million a year. Fresh water can be barged very cheaply; in areas where fresh water is more valuable than electricity or synthetic fuels, plants could be designed to produce much larger amounts of fresh water.

A portion of the nutrient-rich cold water will be sufficiently warmed in condensing the fresh water for it to remain near the surface of the ocean, where it can be used in food-related projects. (An experimental mariculture farm based on nutrient-rich cold water has been in operation on the island of St. Croix for several years.) Depending on the required number of tons of water per kilogram of fish, income could range from $7 million to $80 million per year.

If gases such as hydrogen, oxygen, carbon dioxide, and nitrogen - all of which have important industrial uses - are produced on sea thermal plants, it may be a natural step for these plants to act as bases for major refining and manufacturing processes. The possibilities of locating aluminum reduction factories on board sea thermal plants or nearby on shore are one example. Several countries with large bauxite deposits, such as Jamaica, are in the tropics near the sea thermal resource. Yet, currently, bauxite ore is transported as far away as Canada, where it is then made into aluminum - an energy-wasting proposition. ERDA, and the U. S. Maritime Administration have made grants for the study of potential of sea thermal industrial complexes.

The main product of the first sea thermal plants, however, will probably be electricity. Hawaii, Puerto Rico, and Florida have sites near centers of high demand for electricity. According to a privately funded feasibility study, underwater cable power transmission is feasible, costing $13 million for a twenty-mile cable system, or 5 to 10 percent of the total capital cost of a 100-megawatt plant.

[Extracted from Environment, Vol. 18, No. 4, May 1976. Copyright © , Scientists' Institute for Public Information, St. Louis, Missouri, 1976.]

Note: The U. S. Energy Research and Development Administration has confirmed its present interest in exploring sea thermal power, but stressed that any cost estimates are still speculative.

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